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DESCRIPTION

—OF—

S. R. KROM'S

SYSTEM AND MACHINERY

—FOR—

Dry Crushing and Concentrating

ORES.

RECEIVED THE HIGHEST AWARD at the CENTENNIAL EXHIBITION.

INDEX.

CHAPTERS ON ORE DRESSING.

New York, October, 1876.

RECEIVED THE HIGHEST AWARD at the CENTENNIAL EXHIBITION.

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CRUSHING AND CONCENTRATING ORES.

INTRODUCTION.

The improvements recently made in the system of machinery devised by me for *crushing, sizing and concentration* of *ores*, and the information and experience gained in the course of introducing the system on a large scale, render a new edition of my pamphlet necessary.

It will not be out of place to repeat, in this edition, the objects in view and results I sought to obtain—viz., the production of machinery better adapted for the concentration of ores, to supersede the wasteful and imperfect system of wet concentration, and machinery better adapted for the work of crushing and sizing. In other words, the production of complete machinery constructed on the best principles, and of the best workmanship and design, *for the entire operation of crushing, sizing and concentration of ores, including a simple means of drying the same.*

This class of machinery for crushing and separating ores is a novelty, but I believed that whenever the subject should be fully presented and understood, the very best machinery would find the readiest sale. In this belief I have not been disappointed, as already I have the assurance that the demand will justify the great labor and expense incurred in the undertaking. The introduction of any new system, however simple or good it may be, has always been attended with many obstacles, and the introduction of improved machinery, and the methods of crushing and concentrating ores, has proved no exception to the rule. But whatever doubt has existed, or still exists, is, I think, due entirely to a neglect to examine the subject. Thus far no one has, to my knowledge, doubted the efficiency of the crushing and screening machinery illustrated; only the dry system of concentration has received criticism, but I hope to make the whole subject so clear

in the following pages, that all must admit my claims to be well-founded and true.

The objection raised, in the beginning, to the dry system, was that the ore would always have to be dry, which would in many cases add to the expense, and that the dust raised by dry concentration would prove objectionable. But it is becoming known that the advantages of dry crushing and sizing, coupled with a simple means of drying and removing the dust, remove all the objections, *and, moreover, that wet crushing and sizing is practically impossible* IN VIEW *of the superior advantages offered in treating the same ore in a dry state.* The dust complained of, therefore, commences with the crushing, and ends with the sizing, either in wet or dry concentration, as the dust from concentrating is very slight; but the dust is removed from all parts of the mill as fast as made, and deposited in a settling chamber, and saved for subsequent treatment by means of the exhaust fan and pipes shown in the accompanying plan.

Another question some have endeavored to raise against the dry system is that water is theoretically the best medium. I shall be able to show the fallacy of such an opinion, and to demonstrate, both practically and theoretically, that air is the best medium, so that, not only will it be seen that my system of machinery is better adapted for the purpose in question than anything hitherto constructed, but also each machine possesses theoretically the best principles of operation.

S. R. KROM,

Engineer.

CRUSHING

OR PREPARING ORE FOR CONCENTRATION,

AND THE MACHINERY BEST ADAPTED THERETO.

An ore to be concentrated must be granular instead of pulverized, and any system of crushing which diminishes the percentage of dust or "slimes" to the minimum amount, is the proper one to adopt.

The subject will be understood by a study of the following figures:

Ores from Rollers, crushed to pass 100 mesh screen to the square inch, give:

Granular grains ---------------------- 88 to 90 per cent.
Flour and dust (which will pass screen of
10,000 meshes to square inch) --- 12 to 10 per cent.

And ores from Rollers crushed to pass a screen with $\frac{5}{32}$-inch holes give:

Granular grains -------------------------- 92 per cent.
Dust passing screen of 10,000 meshes to square
inch -------------------------- 8 per cent.

And according to Kustel (following Rittenger) wet crushing under stamps, through $\frac{5}{32}$-inch holes, gives:

Sand ----------------------------------		32 per cent.
Flour ----------------------	32 per cent.	68 per cent.
Dust ----------------------	36 per cent.	

Again,

"The average loss at large of poor argentiferous ores in concentration by water is with

Coarse sands	40 per cent.
Middle fine	35 per cent
Slimes	60 to 70 per cent."

From the above it will be seen that rollers produce in crushing through $\frac{5}{32}$-inch holes 8 per cent. of flour and dust, and that stamps produce in similar coarse crushing 68 per cent. of flour and dust, and that the loss in dust and flour is very much greater than in the coarse grades, amounting in *wet concentration* from 60 to 70 per cent.; or, to substitute data furnished by the dry concentration works at Star Canon, Nevada, the tailings, from low grade De Soto ore, gave the following:

Coarse tailings, per ton	\$3.23
Middle fine " " "	3.67
Fine " " "	8.00

It will therefore be observed that the finest grades of crushed ore are the most difficult to concentrate and in which the greatest loss occurs, and that, moreover, the very finest portion of the crushed product cannot be concentrated by any mechanical means whatever, as it is well known that some portions will float in the air, and a *much greater portion* will remain suspended in water. For example:

"Battery sands, crushed through a No. 6 slot screen, contain on an average of slimes which remain suspended after three minutes rest in still water, 19 per cent." (*Commissioner Raymond's Report of* 1873, page 332.)

It will not be necessary to further elaborate the subject, as it is well known that concentration depends on the difference of specific gravity, and that when ore is crushed so fine as practically to have lost its specific gravity, concentration is impracticable.

From the above statement it will be manifest that a granular condition of the ore is absolutely essential to con-

centrate with any degree of success, and our aim must be to employ the kind of machinery which will produce the least amount of floating dust.

It seems hardly necessary to explain the fact why rolls produce so small a percentage of dust in comparison with that from the stamp mill, since the reason is obvious: the jaw-crusher, and also the rolls, when properly applied, simply break up the ore, and all particles, which are fine enough, fall immediately away, receiving no further crushing; whereas, in the use of the stamp mill, the blows continue to fall on some portions after they are already too fine, simply because the manner in which the crushed particles escape from further blows is mostly accidental rather than positive. The stamps may fall repeatedly on the same particles after they are already fine enough, because the splashing which the fall of the stamp produces may not carry such, at once, through the screen.

Aside from the fact *that stamps are totally unfit for the purpose of preparing ore for concentration*, it is doubtful whether their use is advisable under *any* circumstances; but my purpose would be accomplished in showing in what manner ores should be crushed for concentration, and the proper machinery for the purpose. I shall, however, go a step further and institute a comparison in the matter of cost between the two systems of crushing, viz., wear and tear and power consumed, in order that the question of economy shall also be demonstrated and understood.

In regard to the wear, breakages and power consumed in crushing with stamps, and other features incident to their use, I take some data from U. S. Commissioner Raymond's Report of 1873, page 330; and Report of 1874, page 179.

"A shoe lasts from 21 to 43 days—on an agerage 33 days, crushing 79 tons of rock. Wear, $1\frac{1}{4}$ lbs. of iron per ton of rock. The die lasts on an average 7 weeks, crushing 100 tons. Wear, $\frac{6}{10}$ lb. of iron per ton of rock. The stem

breaks generally square across the fibre near the upper face of the head, and wears, without breaking, about 60 weeks, crushing 864 tons. When the irons are new and of fine quality, the breakages are rarer, occurring, perhaps, but once in 120 weeks. The rewelding, including the necessary new iron, costs on an average $10. The stems, as well as the cams, last at least ten years. The battery linings last six months. The tappets from two to three years."

It is seen, therefore, that shoe and die crush on an average $89\frac{1}{2}$ tons of ore, and the wear of the iron from shoe and die average $1\frac{3}{4}$ *pounds per ton of ore crushed;* but only about $\frac{2}{3}$ of the actual weight of shoe and die is worn in use. So, taking into account the portion cast aside with the portion worn, the consumption of iron amounts to 3 lbs. per ton of ore crushed.

Again, the data furnished by Professor Trippel, found in Commissioner Raymond's Report of 1874, page 197, supply reliable statistics of the wear of stamps when crushing hard quartz:

MANHATTAN MILL MILLING EXPENSES PER TON OF RAW ORE.

1873.	Labor.	Fuel.	Supplies	Quicksilver.	Salt.	Official Labor.	CASTINGS.	Hauling.	Average Total.
January......	$10 04	$10 32	$1 71	$3 33	$3 28	$1 02	**$1 94**	$1 36	$33 00
February......	11 34	10 94	2 20	3 35	3 28	2 00	**2 36**	1 74	37 21
March........	11 88	9 50	2 27	3 05	2 69	1 65	**2 60**	2 12	35 76
April.........	8 45	10 84	2 28	2 44	2 56	1 16	**2 46**	1 88	32 07
May..........	8 16	9 14	1 96	2 25	3 37	97	**2 05**	1 17	28 09
June..........	8 17	8 75	1 89	2 32	2 21	1 00	**1 99**	98	27 31
July..........	8 40	9 13	2 05	2 65	2 64	1 22	**1 67**	1 33	29 09
August.......	8 84	10 03	2 08	2 75	2 52	92	**1 56**	1 10	29 80
September....	8 92	11 11	2 23	2 74	2 98	88	**1 64**	94	31 44
October.......	9 52	11 47	1 90	2 67	2 73	93	**1 65**	98	31 85
						av'rag. cost.	**$1 99**		

Prof. Trippel estimates the proportion of the cost due to crushing alone to be 85 *cents* per ton. And others estimate the *cost* with stamps, in wear, at 50 cents per *ton*, the wear and cost, of course, varying with the hardness of the ore.

DURABILITY OF STEEL CRUSHING ROLLS.

Regarding the durability of steel crushing rolls, although but limited data can be furnished, as their introduction is of recent date, yet the data furnished indicate clearly the value and economy in using steel rolls. It was found, after crushing 2,000 tons of hard quartz at the dry Concentrating Works at Star Canon, Nevada, employing two sets of steel rolls, that their faces had worn one-quarter of an inch, reducing the diameter of the rolls one-half inch.

The steel tires are 26 inches in diameter, by 15 face, and $2\frac{1}{2}$ inches thick, consequently—

$\frac{1}{4}$ inch wear on each tire equals................ $85\frac{1}{2}$ lbs.
$\frac{1}{4}$ inch wear on four tires " .... 342 lbs.

Therefore, in crushing 2,000 tons of hard quartz, 342 lbs. of steel were consumed, equal to $\frac{17}{100}$ lbs. per ton of quartz crushed. At the same rate of wear the tires of two sets of rolls will crush 13,000 tons of quartz to pass through a 10 mesh screen to the linear inch.

As the tires (like shoes and dies of stamps) cannot be entirely worn out, in the above calculation I have allowed 648 lbs. as the weight of metal not worn. This added to the actual wear will amount to $\frac{23}{100}$ of a pound per ton of ore crushed.

Therefore, in wear of crushing faces, the comparison will stand as follows:

In the first example, stamps require 3 lbs. of metal per ton of ore crushed, which, at 6 cents per lb., equals....	18 cents.
And in the second example, as furnished by Prof. Trippel, the *cost per ton* for crushing Austin ore is........................	85 cents.
Rolls require $\frac{23}{100}$ lb. of steel per ton of ore crushed, which, at 16 cents per lb., equals, but not quite........................	4 cents.

Of the steel rolls used at the Star Canon Mill, before referred to, Superintendent T. G. Negus says: "The rolls have worn better than I had any reason to expect. In working about 2,000 tons of ore we have turned them but once, and there is not to exceed $\frac{1}{4}$ inch worn away. I would judge a set of rings would be capable of working at least 10,000 tons of ore."

It will be within bounds, I think, to estimate that the tires of two sets of steel rollers, of the size mentioned, will be capable of crushing 12,000 tons of quartz fine enough to pass a screen of 100 holes to the square inch, and of ore of less hardness the same tires will crush at least 20,000 tons.

It will also be admitted that the breakages and the power consumed in doing the same amount of work, is very much greater with stamps than with crushing rollers.

In the case of stamps, probably not more than half the power is consumed in useful effect; for example: the full amount of power is exerted in running the stamps, whether crushing any ore or not, and this, together with the fact that the stamps must fall part of the time on no ore at all, and often on ore already fine enough, shows clearly that the principle on which the stamps operate is defective; whereas, in the case of rollers, the power consumed is in proportion to the work done. If no ore is fed to them, the only power wasted is in overcoming the friction of the machine, and all ore reduced fine enough is never operated upon the second time. *So, if we should only realize for a moment the difference in the principle and the operation of the two machines, we would need no figures to demonstrate the economy in favor of rollers*, either for crushing fine or coarse.

A few additional words on the efficiency of rolls will be found under the head of "Rolls," etc.

Under date of September 25th, 1876, T. G. Negus, Esq., Superintendent and Engineer of the Georgetown (Colorado) Dry Concentration Works, corroborates the estimate above given of the durability of Steel Rolls.

In crushing 5,000 tons of Ore, the thickness of the tyres on the lower Set of Rolls was reduced by wear and truing once $^1/_2$ inch, and that of the upper Rolls by wear $^3/_8$ inch.

The wear per ton of Ore crushed is therefore not quite $\frac{14}{100}$ of a pound of Steel, and at this rate one Set of tyres will crush over 23,000 tons of Ore, and the cost, including the portion cast off, will be $2^1/_4$ cents per ton.

CONCENTRATION OF ORES.

The mechanical concentration of ores is entirely based on differences of specific gravity, and the subject to be considered is the best means, practically and theoretically, to render available, for the separation of minerals from their accompanying gangue, whatever difference of specific gravity may exist.

Opinions differ, even among the learned, in regard to the process and the kind of machines best adapted for the separation of ores, and whether air or water is the best medium, since ores cannot be concentrated except through the agency of some fluid medium which offers resistance to the force of gravity. No principle has yet been discovered which is better adapted to the separation of minerals than the intermittent and impulsive action of some fluid medium on the crushed ore. The best results thus far obtained are from machines known as "jigs," which employ the above principle.

The reasons why intermittent impulses (of a fluid medium), caused to act on the bed of crushed ore, prove more effectual in separating the minerals contained in it than do other methods, is found in the facts, viz.:—(1) The ore is in this way subjected to repeated liftings and fallings before passing from the machine; (2) The particles meanwhile constantly change position, so as to present the most favorable surfaces to the action of the medium; (3) In well-regulated "jigs," the impulses are given suddenly, having the effect to impart to the ore a succession of quick and sharp blows, lifting the lighter particles of gangue more freely than the heavy mineral; (4) The action loosens and stirs up the mass of ore, and so favors, to a small degree, the gravitation of all heavy particles to the bottom, and the forcing to the surface, at the same time, the lighter material.

Similar results might be obtained (in separation of minerals), providing the ore particles were of some regular shape, by throwing them with great velocity, so as to send them quite a distance. It will be understood that the heavier the particles, the greater distance they will be thrown; and the greater the projecting force, the greater will be the distance of the gangue from the mineral. If thrown with less violence, the nearer together will the ore and gangue fall. On the above principle, the machine spoken of acts—viz.: At each impulse of the ore by the fluid medium, the gangue, or lighter portion, is lifted further or higher than the mineral, or heavier portion; and, by the successive liftings, the gangue is entirely separated, and the more sudden the impulses, the more decided, complete and rapid will be the separation. The intermittent and sudden lifting of the ore better facilitates the separation of *irregular shaped* grains than any other kind of action.

The next branch of the subject which I will consider is, whether air or water is the best medium.

Those who believe water to be the best medium, advance the theory, and on which they found their conclusions, that "the most favorable possible condition under which ore could be dressed would be to have the valuable portion of the ore possessed of a specific gravity greater than the liquid in which the dressing is to be performed. And the worthless portion of a specific gravity less than that of the liquid. For example, let us suppose that an ore consisting of galena, the specific gravity of which is $7\frac{5}{10}$, and quartz of the specific gravity $2\frac{5}{10}$—so finely crushed that each particle consisted of one of the minerals alone—to be located first in a liquid of a specific gravity 5. It is evident that the quartz would remain floating on the surface, while the galena would be found at the bottom of the vessel containing the liquid. Practically, however, it would be found that pieces consisting partly of galena and partly of quartz, and whose specific gravity was less than that of the liquid,

would remain floating, because it would be practically impossible to separate the minerals entirely by crushing, and fulfill one condition of our problem. It is evident, therefore, that if, even in the most favorable condition we can possibly imagine, the mechanical mixture of the ore is such that we can never divide it into pieces consisting entirely of one mineral. We cannot hope, by the ordinary appliances of dressing ore, to be able to achieve perfect results. Worthless and valuable mineral can never be entirely separated when they occur mixed together in an ore." * * * * * "Water and air are the most convenient and the cheapest media in which separation of ores can be made, and both of them have been employed for the purpose. The specific gravity of water, however, approaches more nearly to a mean between the specific gravities of ore and the accompanying gangue, and offers much more resistance to the action of *gravity*, and for these reasons it has generally been preferred to air, except for the dressing of certain ores." * * * *—*U. S. Commissioner Raymond's Report*, 1873, *pages* 427 *and* 428.

It is assumed that the only difficulty in the way of making a successful separation of ores, by means of a liquid of intermediate specific gravity, arises from the fact that "it would be practically impossible to separate the mineral entirely *by crushing*," etc., whereas in the first place the whole theory is fallacious; and in the second place, if the theory were correct, the irregular shape of the grains would make the separation of ores by such a medium impossible. To demonstrate the fallacy of the theory, I will note a few examples, viz.: Cubes of lignum vitæ (specific gravity 1.333) will readily sink in water, while flat pieces will as readily float. Again, small cubes of pure gold and *also* of *platinum* will float on mercury. Mercury possesses a specific gravity of 13.580, gold 19.361, and platinum 22.069. Another example where a denser body will float on a less dense body is the case of cast iron

floating on molten iron; and, also, the well known tendency of substances when finely divided to lie on the surface of a liquid of less specific gravity.

So I think by these facts it can be demonstrated that dense liquids are the least suited as a medium for the concentration of ores. In the case of platinum and mercury we have a difference of 9 in specific gravity, which is a greater difference than what is named in the paragraph quoted as sufficient to cause separation.

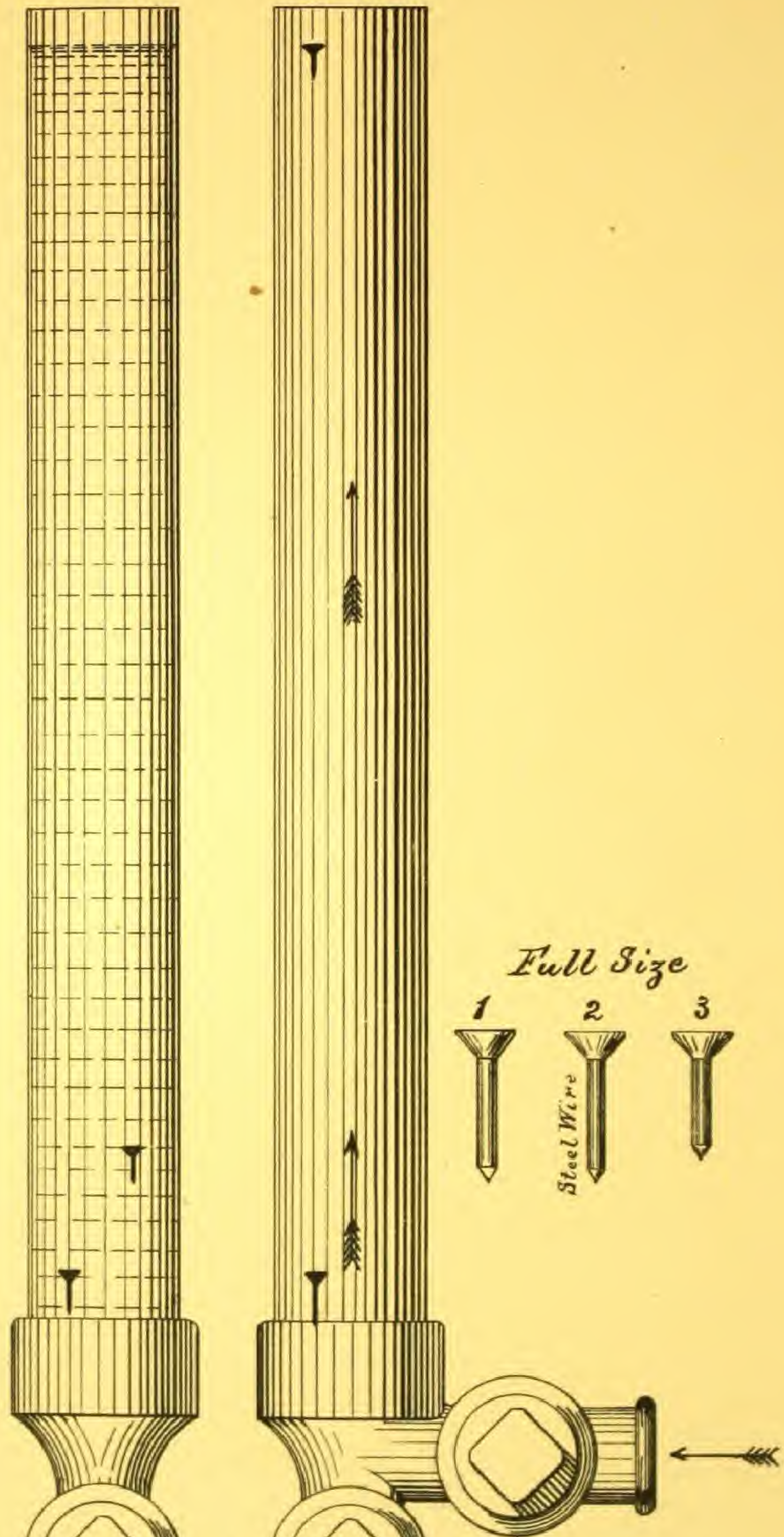
In order to make another demonstration clear, which will prove the superiority of a less dense medium for the separation of ores, I again quote a paragraph from same report of U. S. Commissioner Raymond, of 1873, page 432.

"From a comparison of the ratio between the volumes and absolute weights of equal falling spheres of galena and quartz, in water and in air, it will be seen that in order to do good work with any machine for either wet or dry concentration, a previous accurate sizing of the stuff to be treated is necessary. More particularly is this the case in the dry process, for the difference in the size of equal falling bodies of different densities in air is so much less than in water. A quartz sphere must be four times as large in diameter, contains 68 times the volume, and weighs 23 times as much as a galena sphere that behaves in similar manner, in falling through a column of water. But in air the sphere would only have to be $2\frac{8}{10}$ times as large in diameter, contain 24 times the volume, and weigh $8\frac{37}{100}$ times as much. In either case, however, the importance of a careful sizing is at once apparent."

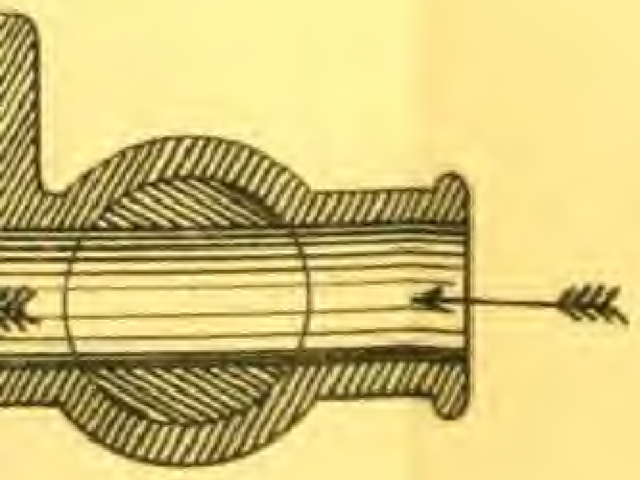
In the foregoing paragraph it is *again* asserted that water has a greater margin for separating ores than air, but practical results of dry concentration prove the reverse to be the case; and, besides, some experiments lately instituted demonstrate, theoretically, that in air we have the greatest margin for separation.

To illustrate this theoretically I erected two glass tubes, each 2 inches in diameter and 8 feet high. One of these

Water Air



Full Size



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tubes I filled with water; through the other I forced a regulated blast of air. I found that, practically, as above stated, $\frac{1}{8}$ inch globule of galena, and $\frac{4}{8}$ inch globule of quartz, fall in equal time in the column of water. But when the blast of air was regulated to retard the galena in falling to the same extent as water, then the $\frac{4}{8}$ of quartz was sustained by the blast of air, and did not fall, while the galena fell as rapidly as in the tube of water. I also employed bodies of other forms, such as shown in the cut marked 1, 2 and 3.

In experimenting with these I regulated the current of air in the air tube, to give the same resistance as water would to the falling bodies of equal weight and size, so that when I let fall two of equal weight and size (1 and 2), one in the water, the other in the current of air, both reached the bottom in equal time. I then let fall No. 1 and 3 in water, and when No. 1 reached the bottom, No. 3 was about 10 inches behind; and next I let fall the same No. 1 and 3 in air; No. 1 fell in the same time in the air as it did in the water, but No. 2 did not fall at all. Thus demonstrating that instead of less margin, we have in air a much greater margin for separating ores than in water. Before making these experiments I expected to find a margin, for separating ores, in favor of air, but did not anticipate it would prove so great. But the experiment proved that $\frac{1}{8}$ globule of galena, and $\frac{4}{8}$ of quartz, which are equal falling in still or moving water, can be separated by air. The results correspond exactly with the results obtained in practice—viz., that with less sizing, better results can be obtained with air than can possibly be reached with water. It *should not, however, need the experiments just related*, to *prove that air is the superior medium*, for it should be understood by simple reference to what is already admitted in regard to the theory of concentration—viz., the requirements to effect separation are, first, differences of specific gravity; second, a proper agitation

of the crushed ore by a fluid medium, so as to force the lighter gangue to the surface, and allow the heavier to sink or remain at the bottom.

I need only discuss the latter condition. *If air would not properly agitate or lift the ore intermittently, then air would be out of the question. But air is made to act upon the crushed ore, so as to suspend it intermittently, in rapid succession, or a continuous blast will carry all before it, just as a stream of water would. Therefore we have in air a medium which will act with sufficient force and power to properly agitate, suspend and lift the ore, and, on account of its small density, the ore can be lifted and allowed to subside from 420 to 500 times per minute, and does not, like water, afford a current or stream sufficient to carry away the mineral.*

Another fact may also be properly mentioned, which is of some importance—viz., that dry ore particles in the operation of separation slide by each other more freely, that is, with less friction in air than they do in water. This may be proved by noting the angle at which a pile of dry ore will rest in air, and the same ore in water. Dry ore, sized between 10 and 20 mesh screens (to the linear inch) rests in air at an angle from base of 35½ degrees, but in water at 2 degrees steeper angle. If wet ore in water flowed as freely as dry ore, the buoyancy of water would cause the same ore to rest at a less angle in water, instead of a greater angle.

By reference, again, to the quotation made, it will be seen that the ideas given, that separation is due to the difference in time of falling of the mineral and gangue after each impulse or lift, whereas the separation takes place at each lift, on account of the lighter being lifted further than the heavy; for when the impulses are properly adjusted, the lighter is the only portion decidedly raised, while the heavier is but slightly acted upon, and the amount of separation that takes place at each subsidence of the ore is too slight, if any, to be taken into consideration. It will be readily understood, then, that the buoyancy of water can be no aid in separating ores, but on the contrary it re-

tards separation by limiting the lifts to 120 per minute, and, as I have already shown, in other respects is the inferior medium.

But a still further illustration of the remarkable difference in favor of air as a concentrating medium is found in the fact that the air jig concentrates successfully all the crushed ore except floating dust; that is, all that is not of a grade finer than about $\frac{1}{240}$ part of an inch in diameter is successfully treated by the air process. In practice, at first, I employed a screen of 10,000 holes to the square inch, to take out the dust. All the granular particles up to 10,000 to the square inch are readily concentrated, but lately it is found practicable to employ a gentle current of air to remove the dust, so that all grains up to at least $\frac{1}{240}$ part of an inch go to the separators for concentration. But with water it becomes difficult to concentrate, with the jig, finer grains than $\frac{1}{25}$ of an inch (or a 12 mesh screen).

In several tests made in concentrating *unsized* ore—ranging from such as delivered through an 8 mesh screen to the finest slimes or dust—I have (with Gilpin County, Col., gold ores) found that ten per cent. of the concentrations would pass a screen of 100 mesh, or 10,000 holes to the square inch, and much of which amount, of course, would pass a considerably finer screen. Yet all these mineral particles, so greatly differing in size, can by air be concentrated at one operation, in one pile, and the gangue in another—facts which establish conclusively, and beyond contradiction, that the rule applying with water does not meet the case in dry concentration. Nevertheless, for the best results sizing is indispensable, and I recommend the adoption of three or four grades.

So that, looking at the subject in every point of view, everything considered, both as to the results obtained practically and in a theoretical point of view, air is shown to possess superior advantages as a concentrating medium over that of water.

Superintendent T. G. Negus has furnished me the following reliable results of working three different lots of ore at the Dry Concentrating Mill at Star Canon, Nevada:

66,800 lbs. of ore from De Soto mine, Assay $72.24.

		Total	$2,412 81
Mineral No. 1.—1,013 lbs.—Assay.	$ 722 71	$366 04	
" No. 2.—1,092 " "	1,187 57	648 40	
" No. 3.— 515 " "	1,204 54	305 35	
Dust from Bin, 11.998 " "	138 17	828 88	2,148 67

Or 89.05 per cent. saved.

38,150 lbs. Sheba ore—Assay value per T., $56.72.

		Total	$1,081 93
Mineral No. 1.—1,072 lbs.—Assay.	$441 09	$236 41	
" No. 2.—1,077 " "	559 86	301 48	
" No. 3.— 664 " "	780 40	251 28	
Dust from Cham. 2.881 " "	96 56	139 09	928 26

Or 86 per cent. saved.

3,260 lbs. Seminole ore—Assay value per T., $4.84.

		Total	$7 88
Mineral No. 1.—55 lbs.—Assay.	$ 32 32	$0 88	
" No. 2.—49 " "	86 87	2 12	
" No. 3.—48 " "	135 10	3 24	6 24

Or 80.47 per cent. saved.

Mr. Negus says: "I enclose the results of working three different lots of ore—one from De Soto, one from Sheba, and one small lot of very low grade ore from the Seminole. This I send, not that it is really of any practical value, but to show how very sensitive the machinery is in taking out the mineral where there is only the very smallest amount."

The De Soto and Sheba are the only mines in Star Canon which furnish any ore. The ores are antimonial silver mixed with black sulphurets of silver, a class of ores exceedingly difficult to concentrate with water.

In Cornwall the concentrated tin ores contain all the copper, iron and arsenical pyrites. This concentrated product is charged into a reverberatory furnace and roasted, for the purpose of oxidizing the arsenical and sulphur combinations in order to change the specific gravity. The roasted ore is again concentrated, and sometimes if the ore

is very impure the roasting and concentrating is again repeated.

With air the concentration of Cornwall tin ore is effected more completely without *roasting*.

Also, zinc blende is separated from *galena* with ease and *rapidity*.

Kryolite from spathic iron:

Specific gravity of kryolite.......................2.9

" " spathic iron.......................3.9

Also the various sulphuret ores of silver, zinc, copper and Colorado gold ores are concentrated with a very small loss as compared with the loss following wet concentration.

Emery from quartz or *iron ore*.

Coffee from *stones*.

Iron pyrites or nickel ores from hornblende.

Diamonds and other precious stones from sand, quartz, *gravel*, etc., and many other substances which have too slight a difference in specific gravity to be separated by means of water.

In addition to the advantages of saving a larger percentage of the value contained in such ores as have heretofore been concentrated by means of water, the successful separation or concentration of those which water cannot treat, and the greater rapidity of concentration, may be mentioned the greater convenience and simplicity secured in the USE *of* AIR *as the concentrating medium.*

I should have had for insertion in this edition extended tables of results by the dry process, but obstacles have prevented me from obtaining *proper* tables of work done at the several mills in operation.

In a few months, at farthest, I will be able to give *recent* results obtained by the dry process in a variety of cases. The satisfaction afforded, however, will be incomplete without having the results of wet concentration to offer in comparison. No reliable data exist to my knowledge, or can be obtained, of recent results in wet dressing, as no parties practicing wet ore dressing are willing to publish their losses. In some cases, no doubt, the percentage of

loss in dry concentration will be greater than the results furnished by Mr. Negus. Then, again, in many cases, the losses will be less. The following example will illustrate the benefits following from dry concentration :

TABLE I.

Cost of concentrating 5 tons of ore into one ton, at $2 per ton....	$10 00
Cost of smelting one ton of concentrated ore..................	$35 00
Total cost of reducing 5 tons of ore..........................	$45 00
Cost of smelting 5 tons of ore at $35.........................	$175 00
A difference in favor of concentration on 5 tons of ore of......	$130 00
Hence, on 50 tons of ore per day (the work of one mill).......	$1,300 00
And on the total work of one year of 300 days, a saving of....	$390,000 00

Continuing the comparison between the two methods to the practical results to be secured by adopting the plan of dry concentration, I will assume that we have an ore of which the assay value is $100 per ton, and that a concentration of 5 tons into 1 is effected. I will allow a loss of 10 per cent. in concentration, while it will be fair to assume, again, that when the deleterious gangue rock is removed, the one ton of concentrated ore can be smelted or otherwise treated with no greater loss than 5 per cent. Accordingly, bringing in the aid of concentration, we shall have the following :

TABLE II.

Original value of 5 tons of ore at $100 per ton..................		$500 00
Cost of concentrating 5 tons into 1, at $2 per ton........	$10 00	
Loss of 10 per cent. in 4 tons of tailings..................	50 00	
Cost of smelting, etc., 1 ton of concentrated ore..........	35 00	
Loss in smelting of 5 per cent. of concentrated ore......	22 50	
Total cost of treating 5 tons of ore............................		$117 50
Amount left, over costs of reduction..........................		$382 50

WITHOUT CONCENTRATION.

Cost of smelting, etc., 5 tons of ore, at $35............	$175 00	
Loss of 10 per cent. on 5 tons..........................	50 00	
Total cost of treating 5 tons of ore....	$225 00	
Amount left, over costs of reduction..........................		$275 00
A difference in favor of first concentrating on 5 tons of ore......		$107 50

The above table will enable the reader to judge of the comparative cost of the two methods of treating ores.

Krom's Laboratory Crusher.

Fig 1

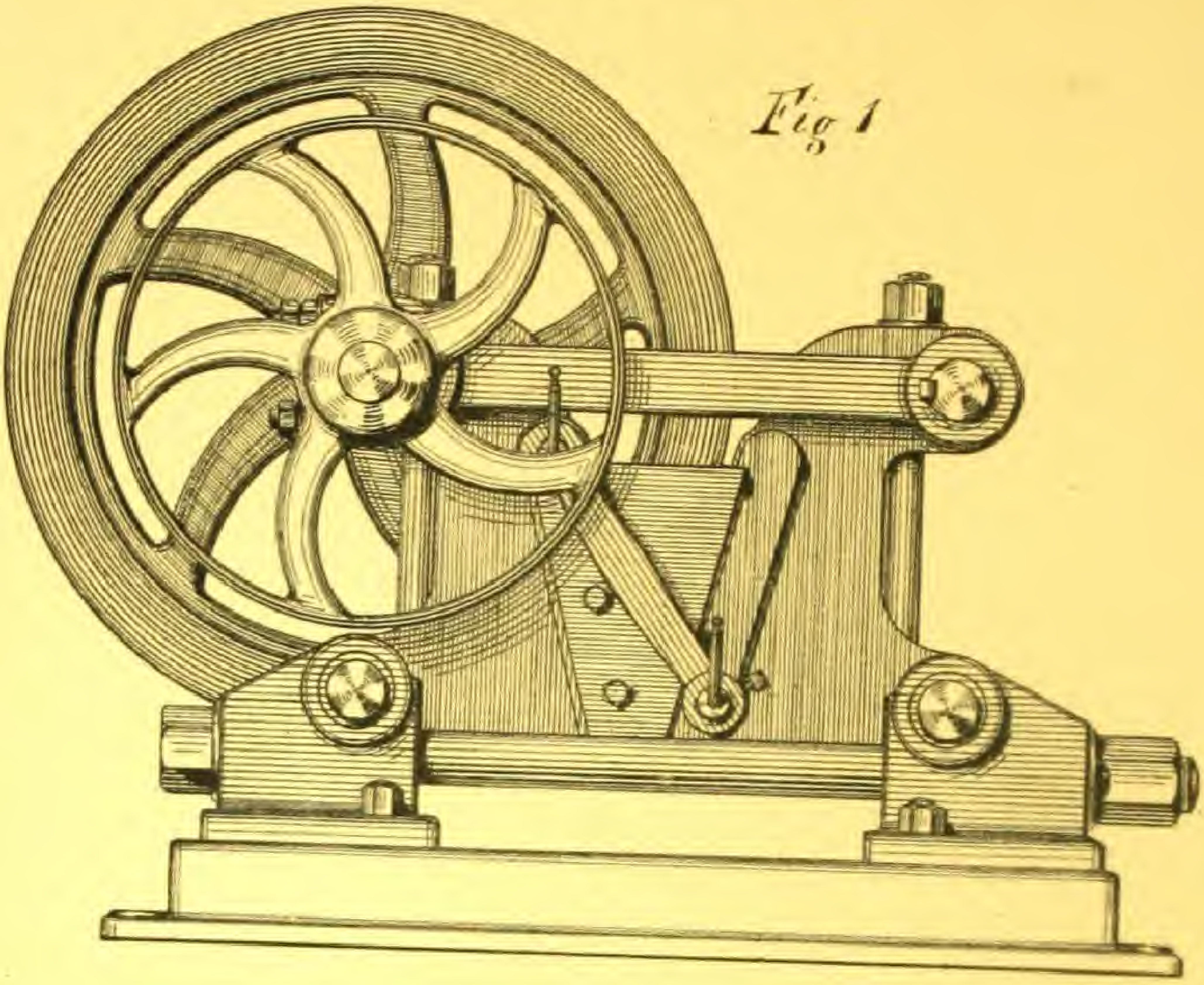
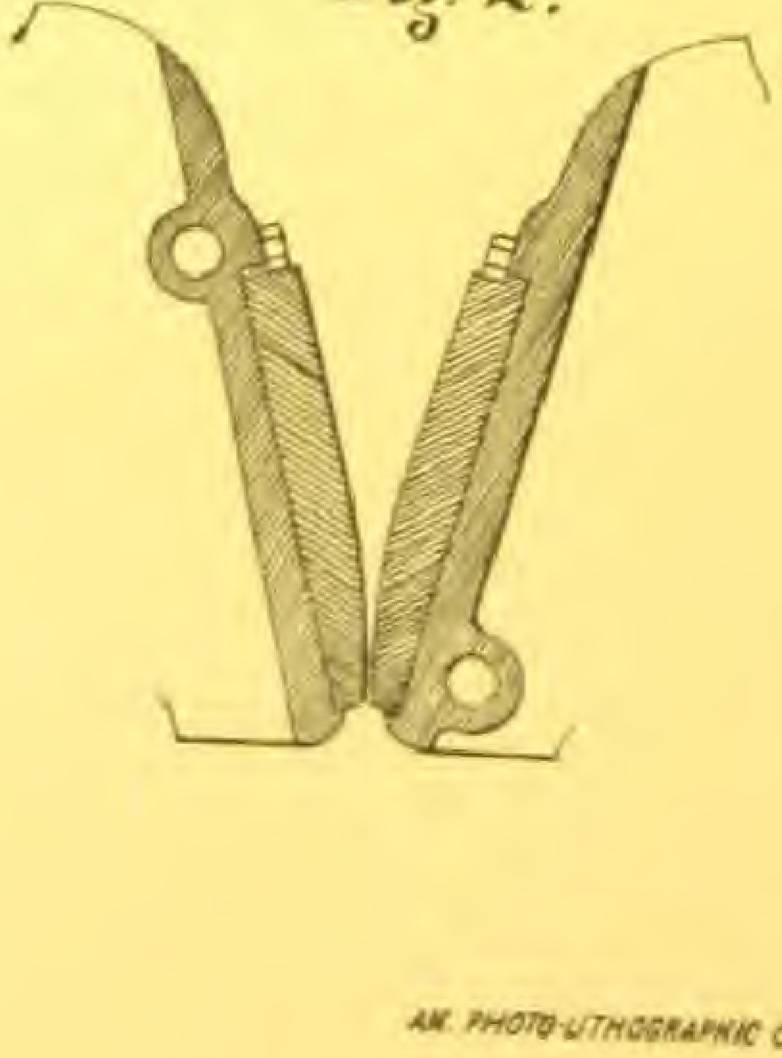


Fig. 2.



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I ask attention, also, to the very important consideration, that without the means afforded us in the process of dry concentration, thousands of tons of low grade ores, and very much of a grade not the lowest, must inevitably be wasted.

Ure, in his article on the dressing of ores, says: "It is not possible to ascertain the value of an improvement which would secure an additional one per cent. from the quantity of orey stuff annually sent to surface from the several mines in the United Kingdom; but if it be reckoned only upon the sale value, it would be scarcely less than £40,000 per annum."

A system of dressing ores such as now described, not to mention the greater rapidity and cheapness of its application, would realize, in the average, at least, I believe, *an additional 25 per cent.* from the quantity of "orey stuff" raised, and the money value of such saving would amount to millions a year in the United States alone.

KROM'S LABORATORY CRUSHER.

The annexed cut represents a Crusher for Laboratory use.

In this machine (unlike any other) both jaws oscillate on centres, fixed some distance from the crushing faces.

The principal feature is the employment of segments of circles, between which the ore is crushed on the same principle as rollers act.

It will be seen (Fig. 2) that the lower ends of the crushing plates are true segments of circles, and throughout all the movement of the jaws they remain at fixed distances from each other, but the top part of the plates recede from each other with straight lines. The crusher can be adjusted, by means of the bolts, so as to produce either fine or coarse crushing.

It is the only machine in the market adapted for Laboratory use.

In a few weeks I will have large crushers to offer for general use, but especially adapted to crushing ore.

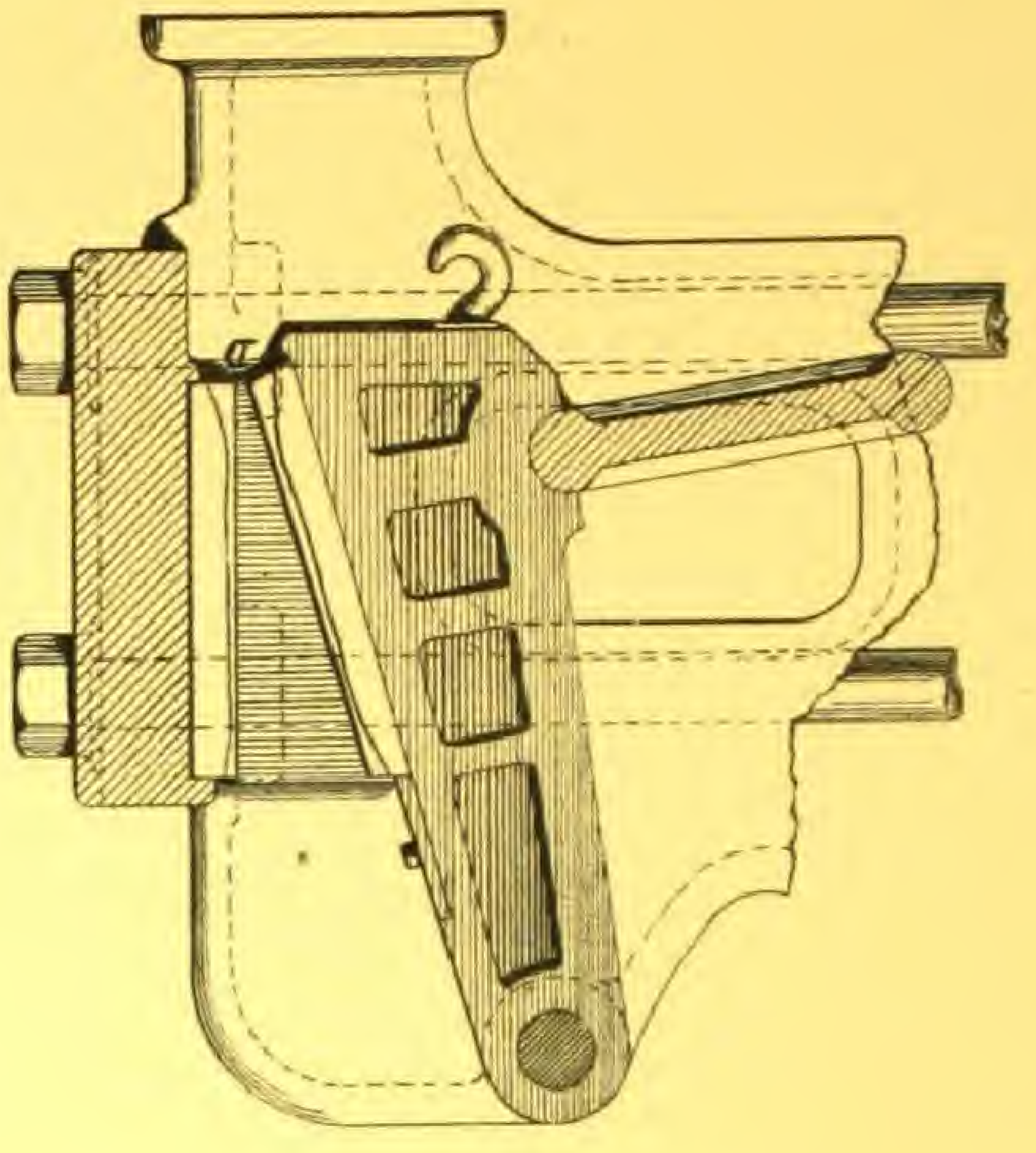
It will be constructed on the sectional principle, and provided with parts which will yield when undue strain is put upon the machine, and thus prevent any breakage.

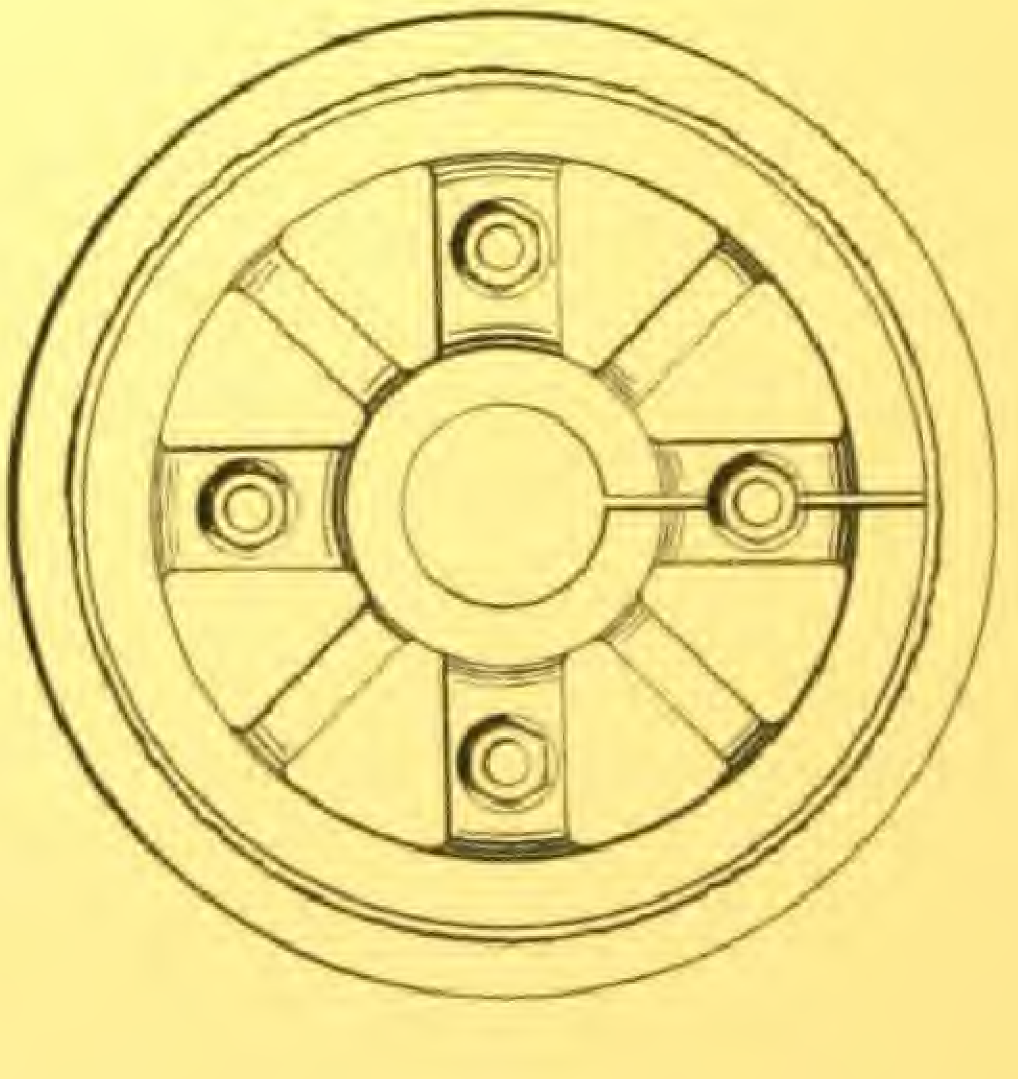
ROLLERS, AND THEIR EFFICIENCY AS ORE CRUSHERS.

Before describing the Crushing Rolls, shown in the accompanying drawing, I will add, as before intimated, some more facts regarding the efficiency of rolls for crushing ores, and the qualities desirable in them. I speak of the rolls as more applicable for completing the crushing of the ore as it comes in small pieces from the Jaw Breaker. For such purpose no other style or kind of machine can be equal to them, when properly constructed; since, first of all, any rolls not only bring into contact, within a given space of time, the largest amount of crushing surface, but also present this in the best manner to the material.

The efficiency of any machine for the crushing of ore depends, in general—*first*, on the condition in which it leaves the crushed product; *secondly*, on the durability of the crushing surfaces; and *thirdly*, on the rapidity with which it will perform the work. Rolls, by acting not to *pulverize*, but simply to *break up finely*, the previously divided material, leave the latter in the best possible condition for concentration, while they present surfaces as little liable to wear rapidly or unevenly, as any other form of crushing faces; and, the movement being continuous and rapid in one direction—so that there is *no lost motion*—the result is to secure crushing of the largest amount of ore, in a given time, and with the greatest economy.

In a similar manner to that which the jaw crusher operates, and so effectually, on large pieces of ore, so do the rolls act on small fragments; namely, as fast as the material becomes reduced fine enough to pass—between the jaws, or in the small space left between the faces of





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the rolls—it immediately falls away, and receives no further comminution. Not so, however, with the stamp mill, which continues to crush long after a large portion of the particles are already too fine; because, in it, the fine material escapes from the action of the stamps rather by accident than by any positive and certain means.

I will also call attention to the superior qualities in Rolls not found in the Jaw Crushers.

On referring to the annexed cut, representing a portion of a Jaw Crusher, it will be understood that all the ore must pass through the narrow opening at the bottom of the jaw; and the principal wear is at this point. It will be near enough correct to say, that the last inch performs the final crushing before leaving the machine, and that the principal wear of the jaw is as indicated by the irregular lines. Assuming, then, that the last inch of the jaw controls the quantity delivered, we have, in a crusher 7x10 at the delivery point, 10 square inches, and this multiplied by the number of bites per minute, viz., 250, makes 2,500 square inches per minute of surface at the limit of delivery, marked D. Calculating the same for rolls, we have in the circumference of 26-inch rolls $81\frac{9}{10}$ inches; this by 15 inches, the width of the face, equals 1,228 square inches in the surface of the roll, and this by the number of revolutions per minute (50), amounts to 61,425 square inches of crushing surface per minute in 26-inch rolls, as against only 2,500 in a jaw crusher of 7x10, running 250 revolutions per minute. Then, again, but a small proportion of the jaw or jaw plates can be utilized, as shown by the irregular line, viz., less *than* $\frac{1}{4}$ of the weight of the metal, whereas, such rolls as herein described, over 80 per cent. of the steel tires is utilized. It will therefore be quite apparent, that in all cases where the ore is not larger than say $1\frac{1}{2}$ inch in size, rolls should be used in preference to any other machine; and, for very extensive operations, the employment of rolls capable of taking pieces larger than $1\frac{1}{2}$ inch would be more economical than jaws.

Great economy, not to speak of other advantages, will be found in employing rolls of considerable size; since not only do such present the best form of surfaces for acting on the ore, but with them, also, the renewal of the surfaces will be less frequently required, on account of the large amount of material in them to wear upon, and thus trueing will be less frequently required.

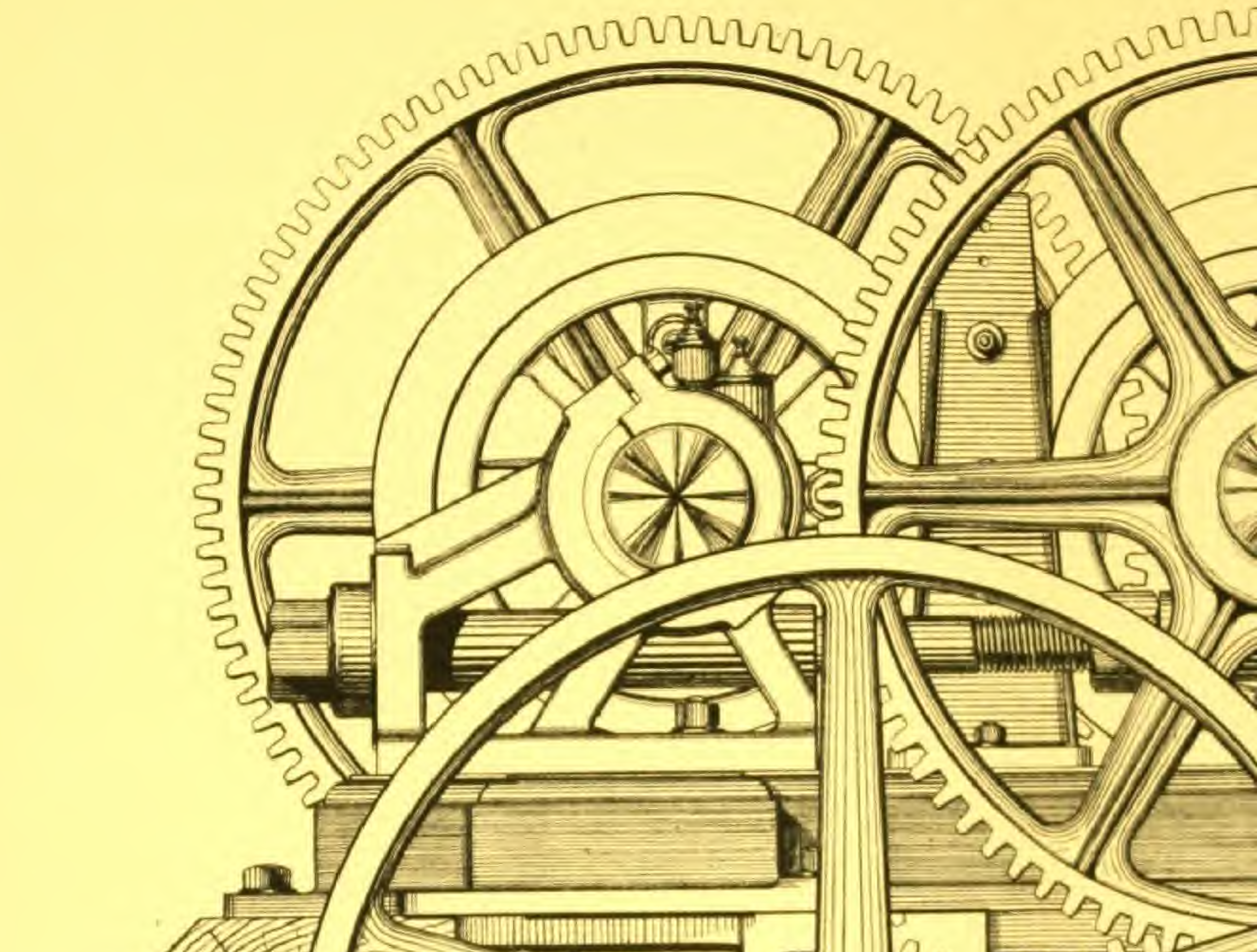
The improved Patented Rolls, the employment of which I recommend, and which are herewith illustrated, may be described, briefly, as follows:

(1.) First in importance is the improvement in the crushing faces themselves. These consist of *steel tires or rings, manufactured expressly for the purpose.* It is confidently believed that these steel crushing faces will continue to give the greatest satisfaction, because the material made use of is more tough and even in its texture than any heretofore employed for the purpose, and the wear of the faces, consequently, more even; and when, in the course of time, these do become worn uneven, the steel is not, as is the case with chilled surfaces, so hard as to prevent its being turned true again. The steel tires described are fitted to inner rings, or hubs, as clearly shown in the drawing, and with the aid of the tool (see Fig. 3 and 4) for keeping the rolls true, they may be worn to ½ inch in thickness before being cast off.

Chilled or hard rolls, when (as they will become in a short time) uneven by use, must be thrown aside, and that although but a small part of the thickness has been worn in actual service; and since the rings must in any case be about 3 inches thick, to have to cast them aside, because already too uneven for further profitable use, when only about ¼ inch of the surface has been worn away, is evidently to subject the operator to frequent and very considerable expense and delay. And so it will clearly be seen that, by the employment of any material that will last equal to chilled or Franklinite iron, at the same time that it allows

Fig.1. Side View.

Krom's Steel Rolls for Crushing



Krom's

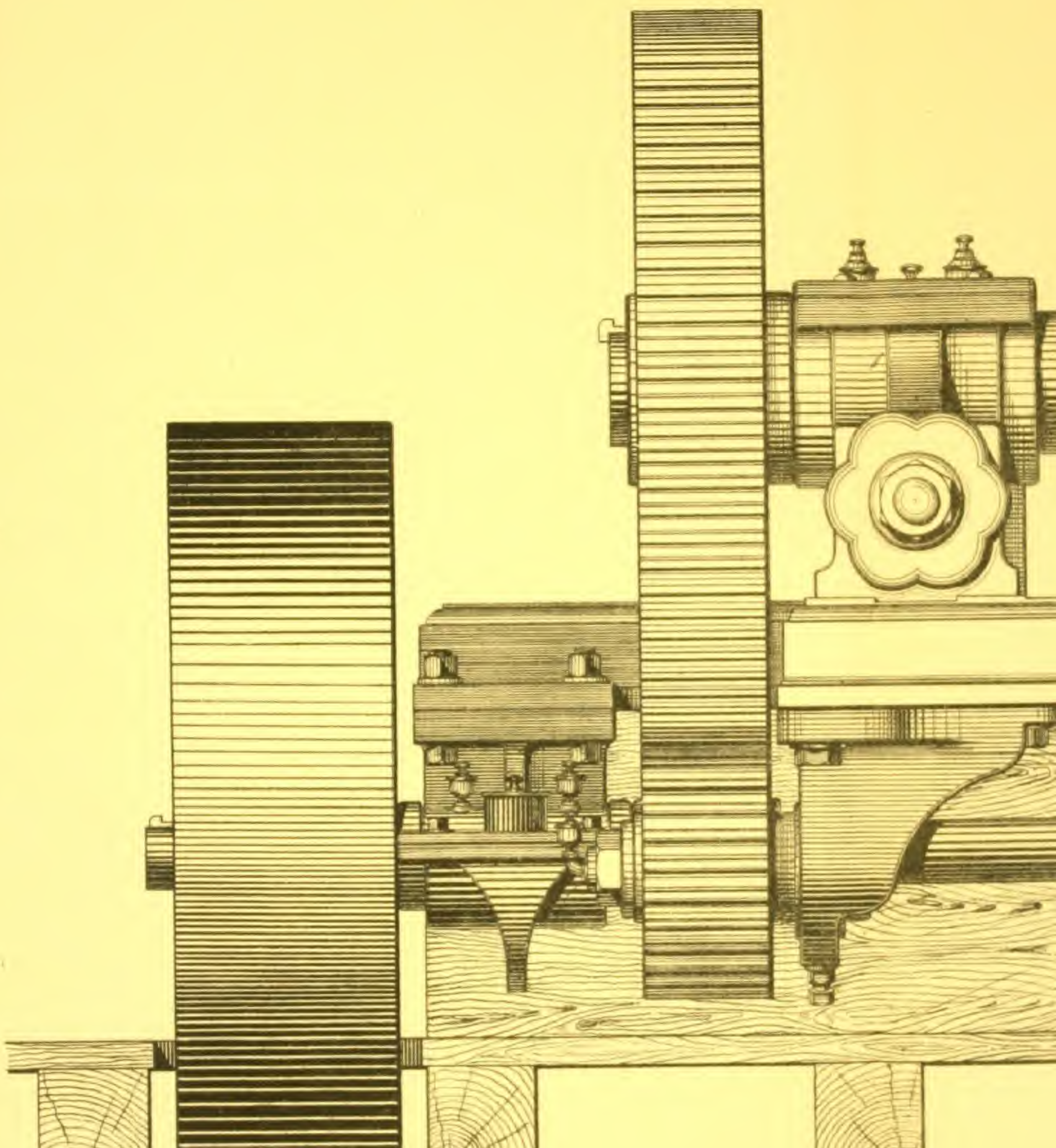
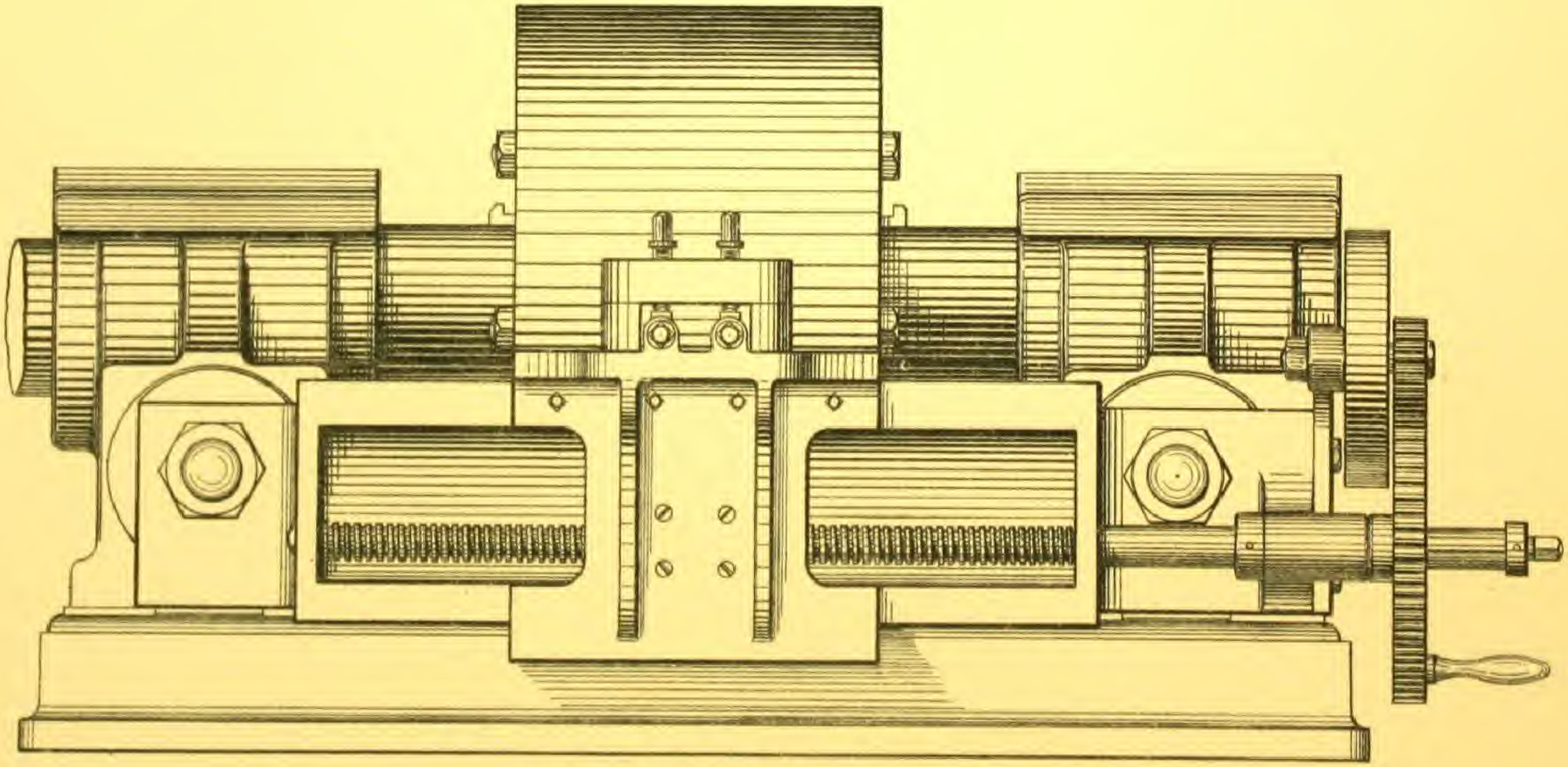
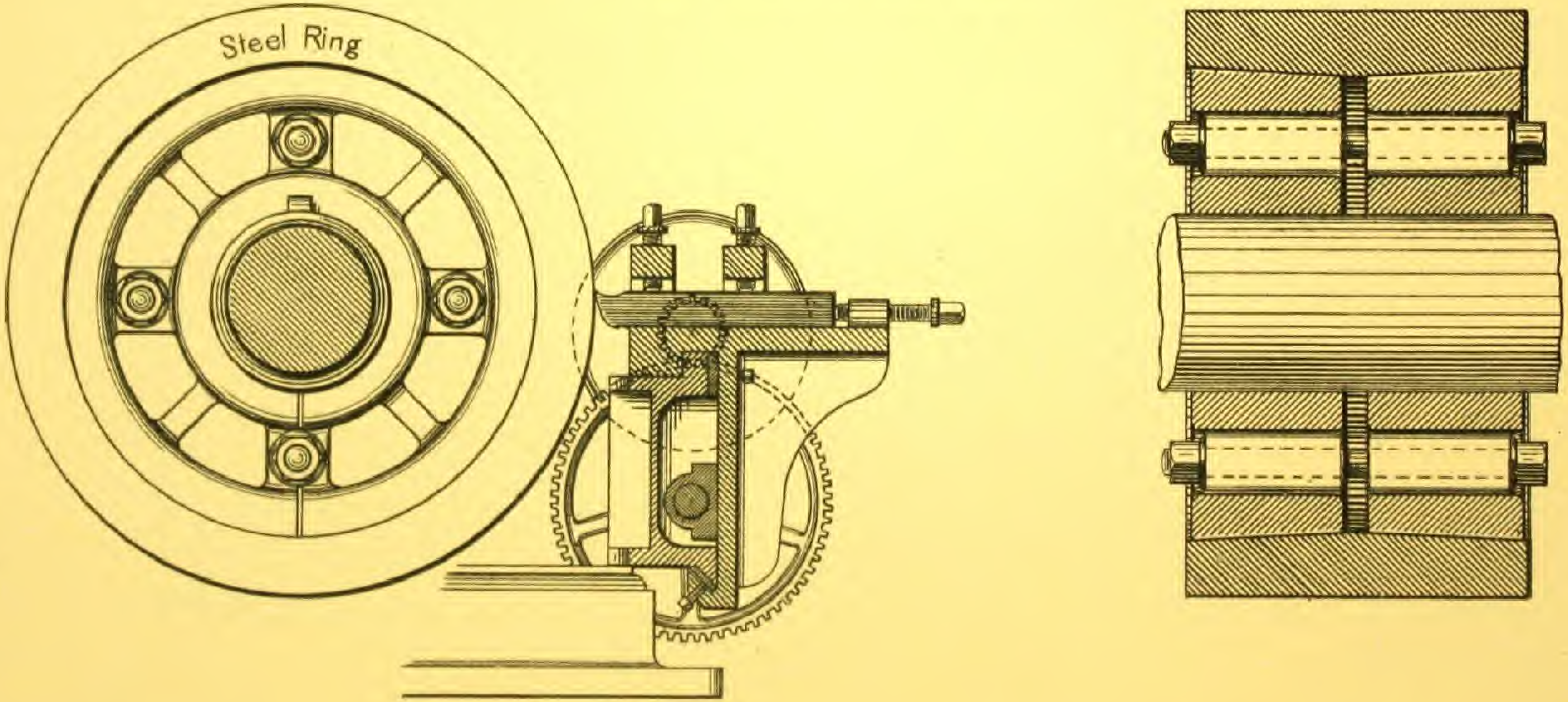


Fig. 3. View showing lathe attatchment for turning rolls.



Patented July 16, 1872.

Fig. 4. Sections of Fig. 3.



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of turning true when uneven, and admits also of being worn quite thin before being cast aside, a really considerable margin is at once secured for the introduction, at the beginning, of crushing faces that are in themselves more expensive. Therefore, although the first cost of steel faces is greater, there is great economy from their use. Still another point here, which should not be overlooked, is the fact of the great disadvantage of employing any material (such as chilled iron) that in wear must go from bad to worse in unevenness, until wholly unfit for use; that is, being obliged to use an imperfect roll for a long time before it can be put aside as entirely worthless

(2.) The second improvement consists in the employment of steel shafts of large diameter, to prevent any spring or bending of the journal, and also to give a large bearing surface, for enduring the great pressure on the journals. The shafts themselves, in the *twenty-six inch roll*, are $7\frac{3}{4}$ inches, and the journals $6\frac{1}{4}$ inches in diameter by 14 inches in length.

(3.) The improvement next to be considered is in the manner of gearing. Each of the rolls is driven, independently, by two 40-inch gear wheels; which, again, receive their motion from two 13-inch pinions, secured upon the main shaft: one of the latter, that is to say, driving the 40-inch wheel on one side of the machine, and the other on the opposite side, through an intermediate wheel, driving the second 40-inch wheel. The intermediate wheel, seen in Fig. 1 below and at the right, turns on a heavy pin, which is so arranged as to allow it to be lowered at pleasure. Accordingly, when the rolls wear, upon dropping the intermediate wheel, the movable roll (that to the right in the figure) can be drawn toward the fixed one (that to the left) by screwing up on the tie-bolts; and, the rolls having been thus again adjusted, the intermediate wheel is then also adjusted to mash properly with the large wheel The left-hand roll, remaining stationary, is

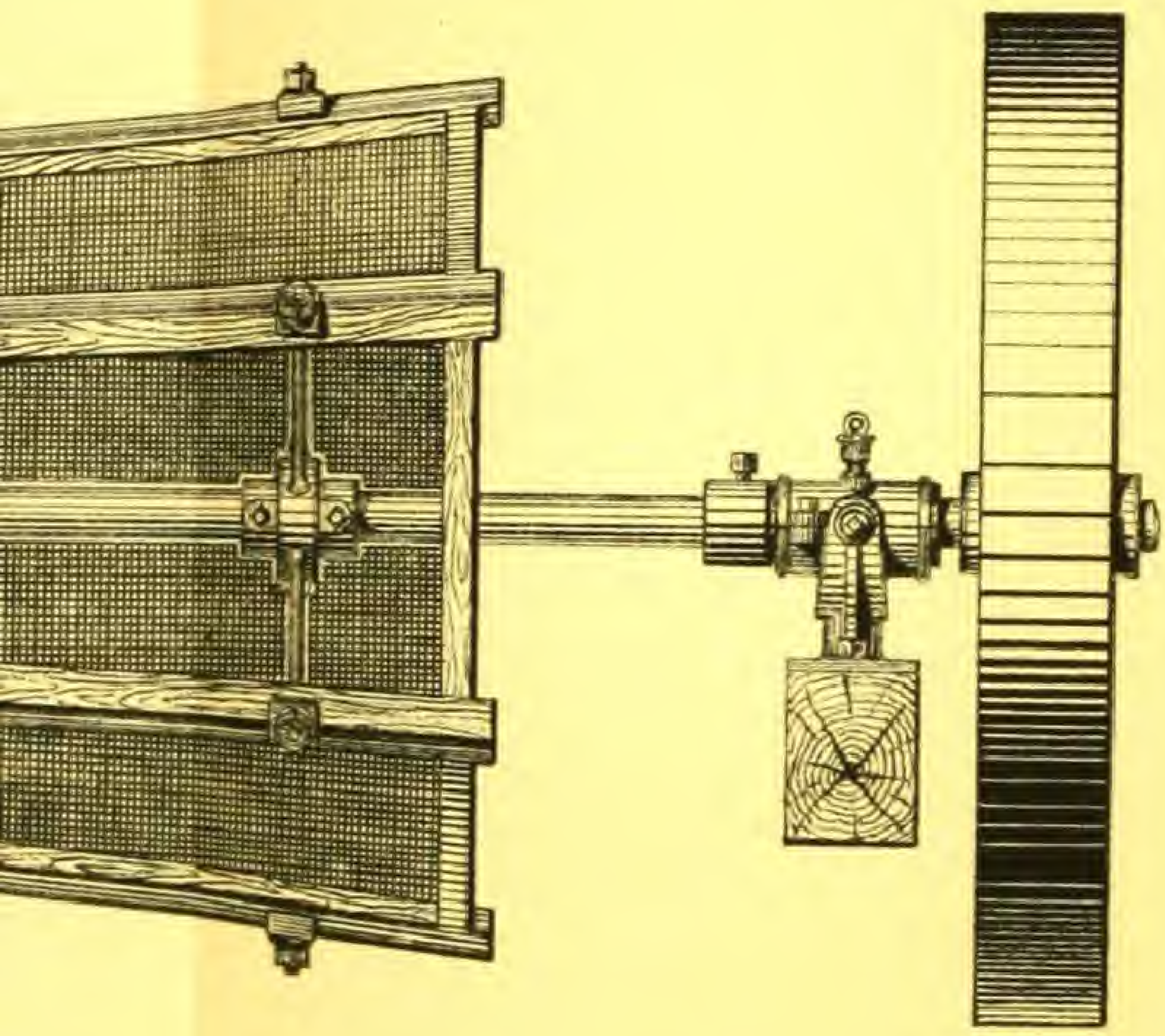
consequently at all times in proper gear; so that, by being able to adjust the right-hand roll, we secure perfect fitting gear in all stages of the wear to which the rolls are subjected.

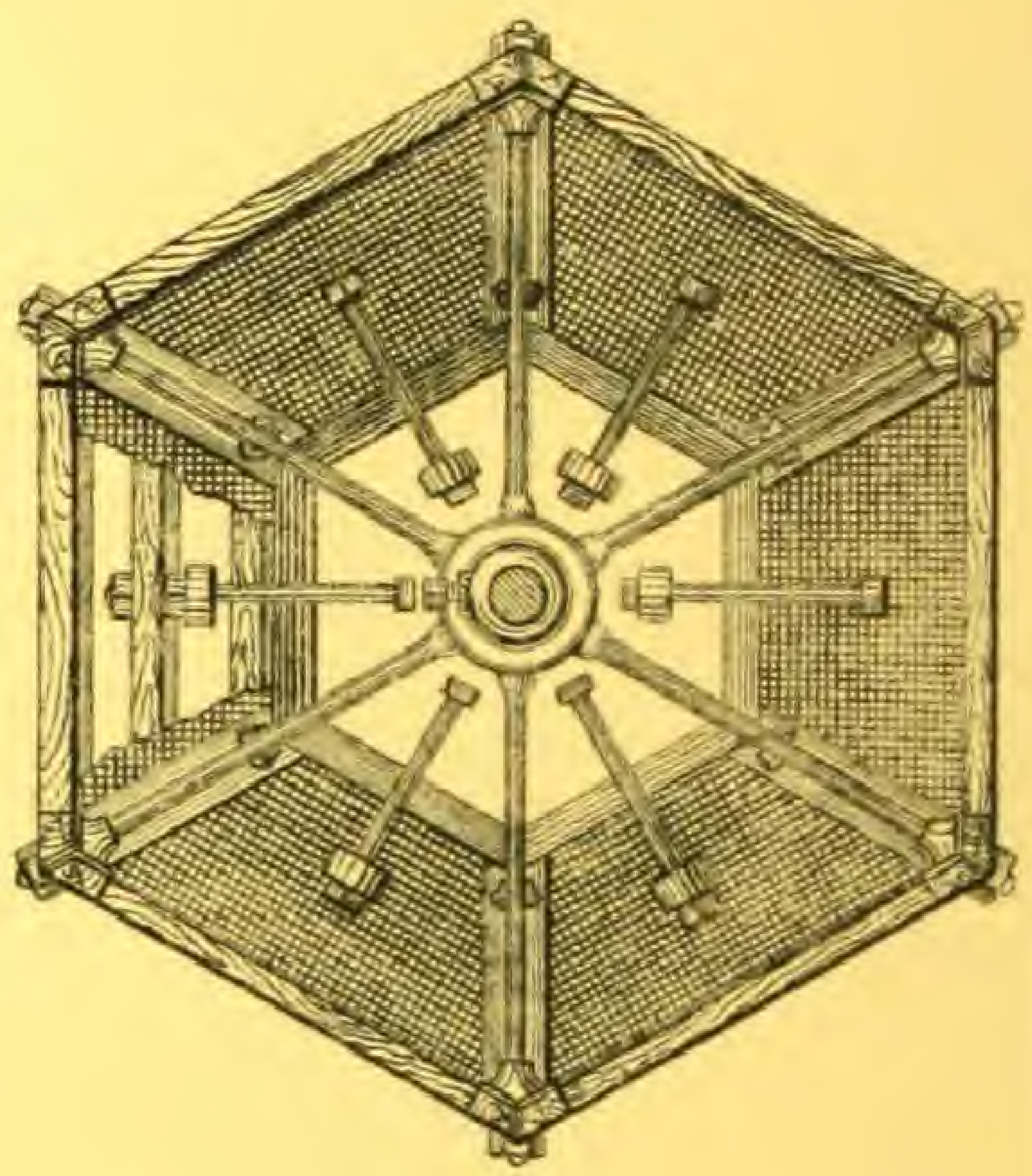
(4.) Another advantage is secured in the use of the *cast-iron cups*, which I have provided, placed under the nuts or heads of the tie-bolts; so that in case any undue strain should occur, as from the falling of iron, etc., between the rolls, these cups will first break, and thus prevent accidents otherwise possible, in the way of straining or fracturing of some important part of the machine. Duplicate cups also are provided for such an emergency. I deem this an important improvement over the employment of rubber springs and weighted levers; since, while accidents are not very liable to occur, we by this means secure evenness of crushing, and save in time by crushing the ore at once, instead of being obliged to pass and repass through the rolls the same material; but when considered advisable springs may be employed, as shown in the figures. The importance of having rolls immovable when doing their regular and legitimate work, and also having them as true as possible, will be understood when we remember that all the ore which passes the rolls not crushed fine enough must pass over the screen and return to the rolls again—perhaps over and over again. Of course any unevenness or moving back of the rolls allows the material to pass untouched, and the screens, which are the most expensive to keep in repair, are worn out for no purpose, as well as the mill generally. The fact is, the very best machinery for crushing, and also for screening and concentrating, with the very best mechanical skill to operate the same, will be sure to pay the largest dividends.

(5.) The wrought-iron tie-bolts (plainly seen in the figure) take all the strain due to crushing the ore, thereby securing the greatest strength with the least weight.

(6.) The sixth improvement consists in mounting the

reen with adjustable bearings.





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whole machine on a substantial cast frame, serving in a manner to render the machine *complete within itself*.

In addition to such improvements in the machine, I have provided—to be attached to the latter—a *slide rest;* this, whenever the steel rings become worn uneven, is brought into use for turning them true again. The arrangement, and mode of applying, are indicated in the drawings, Figs. 3 and 4.

To sum up: what I can justly claim in favor of these Rolls is, briefly, as follows:

1. The steel crushing faces, and manner of securing them.
2. The heavy steel shafts, with composition boxes.
3. The adjustable gearing.
4. The wrought-iron tie-bolts, and breaking cups.
5. Driving each Roll independently of the other.
6. The large bearing surfaces of all the journals.
7. The steel driving shaft.
8. The mounting of the whole machine on a substantial frame.
9. The slide rest, for turning the rolls.

These Rolls are accordingly offered as furnishing the most complete and finished machine, of its class, now manufactured and in the market.

SCREENS.

The plan of *revolving screens* is that which I have adopted, as best suited for the work to be performed; and perhaps the only features particularly requiring notice, in the department of screens, are those in respect to their systematic manufacture, and the adaptation of all their parts to the *sizing* they are intended to effect.

The screens are made larger at one end, in order to give the proper incline for discharging the ore, while allowing the shaft to be placed *horizontal*. By having the screens

themselves cone-shaped, and the shafts accordingly horizontal and parallel with each other, the important advantages are secured of rendering it convenient to drive in the ordinary way by belts, and also of the facility of driving one shaft by the other—an arrangement shown in the Plan of Mill, where the lowermost one is driven directly from the main power, this in turn made to drive the next, and so on.

The bearings of these shafts, as with those throughout the Mill, are self-adjusting; so that, in case the shafts spring or become out of line, the boxes will still bear truly on the journals.

To prevent clogging of the screen, I have arranged hammers or weights to slide on bolts hanging inside of the *screen*, as represented in the accompanying drawing, and the action which is to jar out particles that may have stuck in the meshes. A light blow on the top of the screen serves best to loosen and throw out any particles sticking in the meshes, at the same time that (owing to some elasticity of the frame as a whole) it affects less the lower portion—as is desirable it should do, since whatever jar the screens receive when at the lowest point is likely to fasten the particles only the more firmly.

Rubber cushions or springs placed on the end of the bolt next to the *screen* soften the blow of the hammer at the lower side of the *screen* as *shown* in the *cut*.

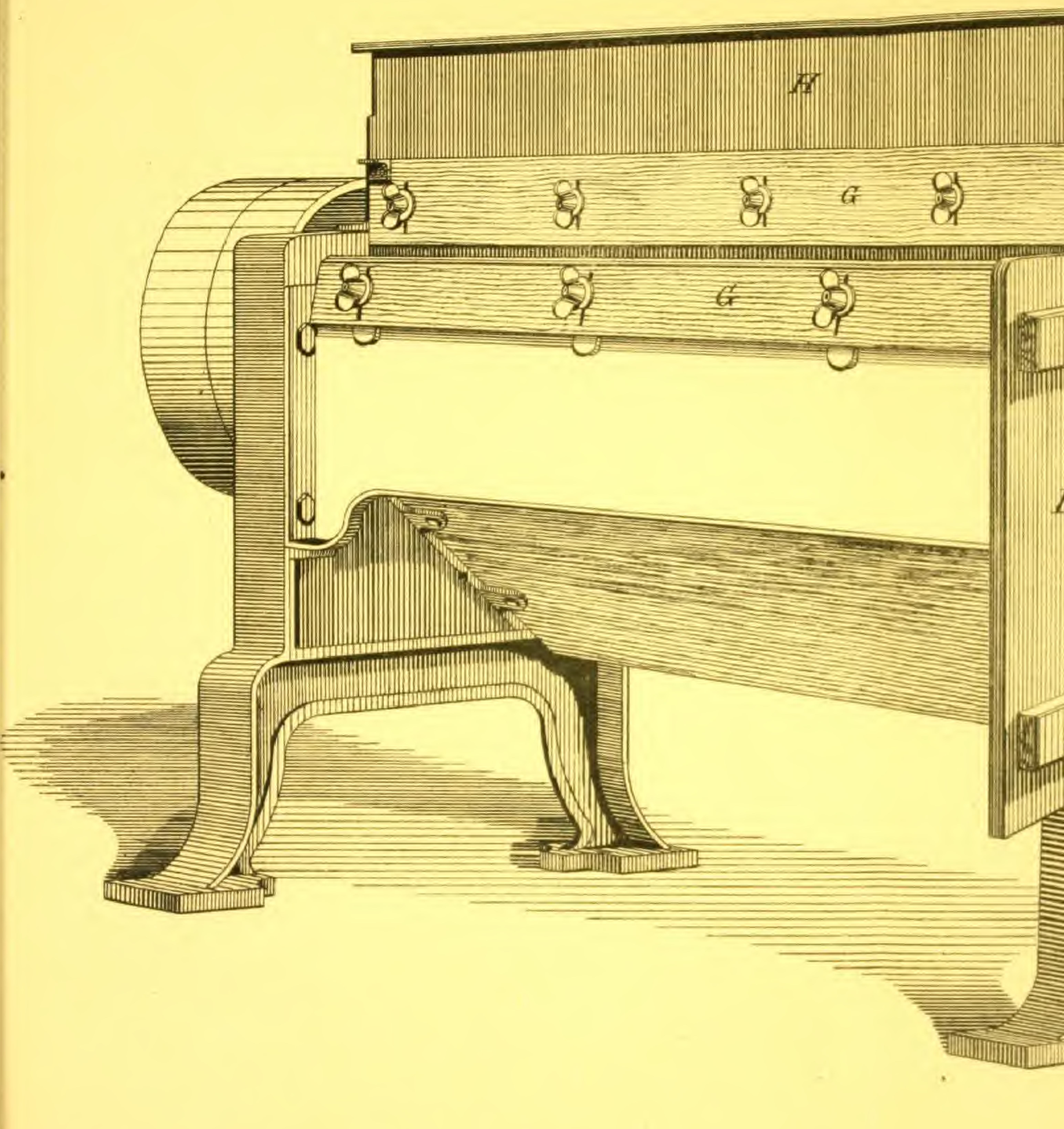
DESCRIPTION OF THE DRY CONCENTRATOR.

The FIRST PLATE accompanying this description is a *perspective view* of the Concentrating Machine, entire; the SECOND is a *transverse sectional view*.

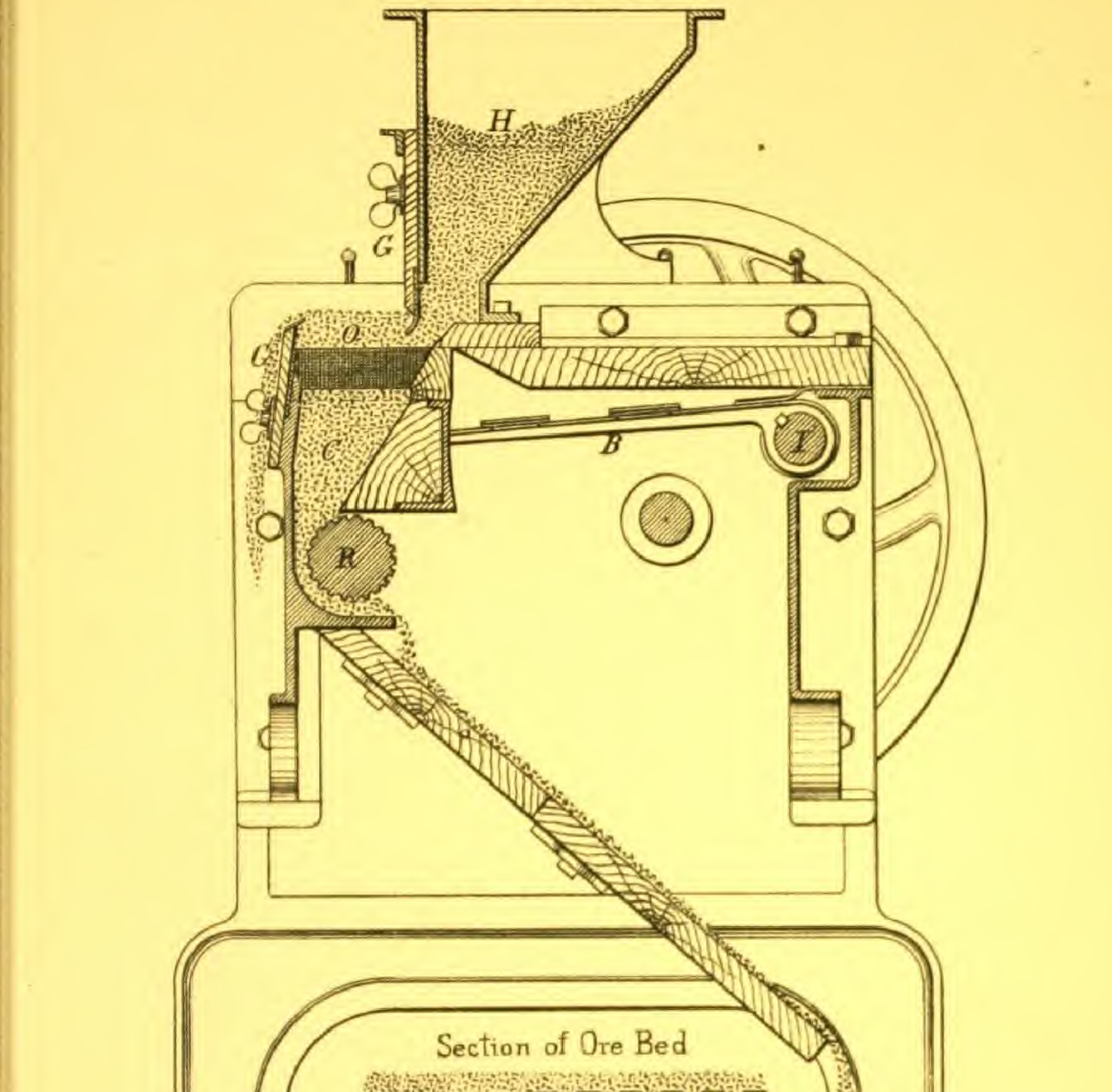
The machine is composed essentially of the following parts: A *receiver* (H), to hold the crushed ore; an *ore-bed* (O), on which the ore is submitted to the action of air; the two *gates* (G G), one to regulate the flow of ore from

End and Side View of S. R. Krom's automatic Dry Ore

Length of machine 5 feet width 3 fee



Section.



the receiver (H,) the other to determine the depth of ore on the ore-bed; a *passage* (C) in which the concentrated ore descends, and *roller* (R) to effect and regulate the discharge of the same; a *fan* (B) to give the puffs of air; a *trip-wheel* (T), *lever* (L), and *spring* (S), to operate the fan; and a *ratchet wheel* (W), and *panel* (P), to impart revolution to the roller (R).

The mode of operating the machine is as follows: Ore is placed in the receiver (H), and the driving pulley set in motion. The trip-wheel (T), fixed on the opposite end of the pulley-shaft, works by its cam-shaped teeth against the lever (L); and by the alternate action of this wheel, forcing the lever in one direction, and of the spring, which at once and suddenly carries it back again, the fan (B) is made to swing on the shaft (I), sending at each upward movement a quick and sharp puff of air through the ore-bed, and lifting slightly the ore lying on it. As there are six projections upon the trip-wheel, it follows that the moderate speed of 70 to 80 revolutions of this per minute will give 420 to 480 upward movements of the fan in the same time, and consequently a corresponding number of puffs of air to agitate the ore; this rate is sufficient to secure steady motion of the heavy balance pulley, and yet not so fast as to produce any unpleasant jar or noise—the machine working smoothly and easily.

The ore-bed is composed of wire-gauze tubes, placed at distances from each other of $\frac{3}{16}$, $\frac{1}{4}$, $\frac{3}{8}$ and $\frac{1}{2}$ of an inch, according to the grades of ore to be concentrated—the finer requiring that the tubes be set nearer together, while the coarser allow of their being farther apart. The ore-bed, situated in front of the fan, as plainly shown in the sectional view, is formed by these tubes—their ends next to the fan being open; and the air from the bellows, entering these, escapes through the top and sides of the tubes, agitating the ore that lies on them, and also that between them near the surface.

The ore between the tubes rests on that immediately underneath, in the passage (C), and sinks as fast as the roller (R), at the bottom, effects its discharge The tubes being open on the lower side, any fine ore passing through the meshes of the wire gauze simply descends with the main body (C), thus preventing any liability of the tubes to filling up.

In discharging the concentrated ore (C), the roller (R) is operated (as mentioned above) by means of the ratchet wheel (W), and pawl (P); and, the latter being carried by a crank on the trip-wheel, it follows that its speed is governed by the speed of this wheel, which also gives motion to the fan (B): by this connection, *the fan*, which effects the concentration, and *the roller*, which discharges the concentrated ore, are made to act *in concert* with each other. The importance of this feature will be apparent, when it is remembered that the amount of ore concentrated in a given time depends on the number of puffs of air supplied per minute; so that, as the arrangement here secures, the motion of the discharge roller *should be* controlled and regulated to correspond with the speed of the fan.

To accomplish more satisfactorily the result sought, the crank which carries the pawl can also be adjusted, by varying its length; so that the speed of the roller may be further regulated, according to the richness of the ore.

As already stated, the upper gate (G) governs the flow of ore from the receiver (H) to the ore-bed; whilst the lower gate (G) is so set as to determine the thickness of the stratum of ore lying upon the latter; the reason for this last arrangement is found in the necessity of increasing or diminishing the depth of the bed of ore operated on, according to the coarseness or fineness of grade—the finer the crushed ore, the thinner should the stratum be.

The strap, with its screw fastenings, serves, *first*, to prevent the roller-attachment of the lever (L) from striking

the body of the trip-wheel, as it falls from each of the cam-shaped projections; and, *secondly*, to regulate the extent of movement of the fan. That is to say, the strap must in all cases be so adjusted that the small roller working against the trip-wheel shall not strike at the foot of the cam—the strap serving in this manner to cushion the blow and prevent noise. Further, by tightening up or slacking off by means of the screw fastening, the fan is carried in its vibration through a greater or less space, producing accordingly a stronger, or lighter, puff of air.

It will of course be understood that the volume of the puff of air required varies with each grade of ore operated upon. Now, with the strap arrangement alone, the volume of the puff can be regulated to the exact requirements of different grades of material. But, as the finest grades of ore demand *so much less* movement of the fan than do the coarser, it is preferable to have an additional means of control; and to supply such, trip-wheels of different sizes are provided along with each machine. It is, in working, better to select a trip-wheel which gives a movement corresponding most nearly to that required, and then to make the nicer adjustments by means of the screw and strap; *but the roller must in no instance strike at the foot of the cam.*

The novel features, then, to be particularly noted in this Separator, are as follows:

1. The ore-bed.
2. " automatic discharge-roller.
3. " fan, for producing the puffs of air.
4. " trip-wheels, and spring.
5. " strap, and adjusting screw.
6. " gate on the receiver H.

(1.) The *ore-bed*, formed of wire-gauze tubes, which are set in a frame a short distance apart, thus allowing the ore to descend between them, is A NOVEL AND ORIGINAL DEVICE for securing the removal of the concentrated ore, as fast as the separation on the bed is completed.

The entire width of the ore-bed in the largest size machine is 4 feet, and along this the tubes, only $\frac{1}{2}$ inch wide, are set, with intervening spaces of from $\frac{3}{16}$ to $\frac{1}{2}$ of an inch: consequently, the total extent of openings through which the ore falls, amounts in the one case to $\frac{1}{3}$ and in the other to $\frac{1}{2}$ of the entire ore-bed. This construction gives a great amount of space through which to deliver the concentrated material, and of course *distributes the discharge over such space;* so that at no single point does the ore sink rapidly, and yet the action of the air is perfect and equal over the entire extent of the ore-bed.

(2.) The second feature in importance is the *automatic discharge roller* (R.) This being driven by the motion that works the fan, and its rate of revolution being at the same time, and in the manner already explained, regulated according to the richness of the ore, it follows that the concentration of the material, and its discharge, are effected in concert: the result is, that when the general speed of the machine slackens, the concentration being of course less, the rate of delivery is (as it should be) correspondingly reduced.

(3.) The third feature is the general simplicity of the device for producing the puffs of air; namely, a *fan* or plate, furnished with rubber valves, swinging on its proper shaft, and directly actuated by means of a single lever (L).

(4.) The next feature requiring notice is the combined operation of the *trip-wheel and spring*, in actuating the fan or bellows-plate. The wheel, by the gradual action of its cams, throws the lever (L) back, and consequently the fan or bellows-plate downward, with a movement as gentle as is possible for one so rapid, when, immediately after, the spring carries the fan quickly upward—the two motions, in this way, securing all the time practicable for the air to fill the space above the fan, and then the expulsion of this with a sudden impulse through the ore-bed, imparting a lift to the ore, as already explained.

The superiority of this particular device over cams, cranks, etc., arises from the fact that, with it, a considerable variation of the speed of the machine does not affect the quality of the concentration, but only the rate, and so, the quantity. If the trip wheel revolves slowly, the number of vibrations of the fan is of course less; but as the spring causes the upward movement, the puff of air is of practically uniform strength, and we thereby obtain at all speeds what we may term *a concentrating stroke of the bellows.*

For, *the more sharply or distinctly the jets of air are given, the more perfect and well defined will be the separation, and the greater may be the varying sizes of the grains. And the more rapidly in succession are the jets of air repeated, the greater will be the amount of work done in a given time.*

(5.) In reference to the action of the strap and adjusting screw, although in itself important, the explanations already presented are deemed sufficient.

(6.) The gate on the hopper (H) compels the ore to flow on the ore-bed as an under-current—and as the puffs are regulated to agitate just perceptibly the heavy portion of the material, it follows that only the lighter portion will rise to the surface and be thrown (as tailings) over the lower gate (G), while the heavy continues to sink through the ore-bed, and to be discharged below.

This feature of the under-flow of ore, just stated, enables us to concentrate perfectly with a very short travel of the material, or in other words, to employ a short ore-bed —a condition of things which proves for several reasons of great advantage; as—

A. By thus having a short ore-bed, we are allowed to extend what we can properly term the WIDTH *of the bed, thereby* GREATLY INCREASING *the capacity of a machine of given size.* All other experimenters have caused the delivery and discharge of the ore to take place over the shorter dimension of the machine, and the travel of the ore over the longer dimension; the exact reverse of this is secured in the machine here described; viz., the distance of travel of

the ore over the bed is only 5 inches, *while the line of overflow is extended to 4 feet, or can be at pleasure made still greater.*

B. A short ore-bed enables us to use a small fan or bellows; thereby reducing the size of the machine, as also the power required to run it, and the vibration attending rapid movement.

C. A more even and uniform agitation is secured, when the ore is confined within narrow limits; and consequently, more satisfactory results are for this reason also obtained.

(7.) The feature last considered leads us naturally to the shape of the machine. Since I have discovered that a short ore-bed, of only 5 or 6 inches length, is *not only sufficient, but in fact much superior*, for the purposes required, and that the width of the bed and extent of overflow can accordingly be greatly increased, thus largely increasing also the amount of concentration for a given size of machine, I am able so to place the fan and to group in compact form all the working parts, as very considerably to reduce the entire bulk of the machinery and frame—the whole being kept to a small and convenient size, in comparison with the amount of work performed.

(8.) The frame is made deep, and provided with a door to inclose the principal working parts—a feature, however, which is not considered among the essential.

Before leaving the subject of the concentrating machine, attention should further be called to the fact, that with it the puffs of air, in agitating or lifting the ore, effect at the same time the delivery of fresh supplies from the receiver, and help to force the tailings over the lower gate, G.

The puffs of air are, at the start, regulated to agitate sufficiently the ore on the bed; but should the richness of the latter increase during working, or too large a supply collect at one time on the bed, the air ceases to lift or agitate the material so much as before; and thus a check is

at once furnished to prevent loss by the overflowing of heavy ore in the tailings. No such check is possible in water concentration; because water moves practically as a solid, and carries all before it.

To sum up, in conclusion, then: *The peculiar arrangement of the ore-bed, which admits of so great an extent of openings for the rich ore to descend through, without interfering with the perfect action of the air on the ore, and the automatic and adjustable mechanism to effect the timely discharge of the same; the complete means of regulating the blast of air; the check which the compressible nature of the medium furnishes, to the liability of too rapid feeding; the far greater freedom with which ore particles sink in air, in comparison with that possible in water, and which renders much sizing of the ore unnecessary; the saving of the fine particles; the economy of labor and power; and the extreme simplicity and durability of the parts throughout, are points in its construction and working which combine to make this Separator superior to all others known.*

All the parts in this machine liable to wear in the course of time are manufactured to duplicate, and, accordingly, can be cheaply replaced.

The machine measures 6 feet in length over all, 3 feet in width, and 3 feet 10 inches height. It weighs, complete, 1,200 pounds, and IS CAPABLE OF CONCENTRATING $\frac{1}{2}$ TON PER HOUR, WITH $\frac{1}{4}$ HORSE-POWER. Besides the large machines, I manufacture smaller ones, of the weight of 150 pounds for the requirements of laboratories and of mining prospectors.

DESCRIPTION OF MILL FOR DRY CRUSHING AND CONCENTRATION OF ORES.

The accompanying plan of mill showing the best arrangement of the machinery for crushing, screening and concentration of ores is designed with a view to economize in the labor and expense required to operate it.

In this plan some of the economical features introduced in practice are not shown, for the purpose of better illus-

trating clearly the operation simply of crushing, sizing and concentrating, including the means of drying the ore.

One important feature omitted is that for weighing after drying and crushing just previous to sizing. The plan adopted is simple and saves a great deal of trouble and expense, and secures greater accuracy in the weight of ore treated.

The mill is represented as built on the slope of a hill or mountain-side, a course securing some conveniences. By this plan the ore is delivered in the third story, and at this point fed to the jaw crusher (1), which breaks the ore into small fragments.

The ore thus broken falls into the drying oven (2) to release it from outside moisture.

The drying oven is made of cast iron. The bottom, as plainly represented, is arranged in step fashion, so as to allow the hot air or fire to pass up through the spaces between the ore. It will be readily understood that such a system of drying will secure the most rapid and economical results. The heat after it passes through the ore with the moisture it carries is conducted away through a flue or pipe in the ordinary way.

At the bottom of the dryer is arranged a shute (*a*) capable of being adjusted at such an angle as just to deliver the ore to the endless belt (3) in a comparatively thin stratum. This belt (3) is adjusted in speed to carry the ore away from the dryer and deliver it to the first pair of rolls (4) at the same rate it is fed to the crusher. If feeding at the crusher is stopped, the carrier belt (3) should also be stopped, as it is essential to have the dryer always quite or nearly full. A shifting belt (B) which is under the immediate and easy control of the man at the crusher, supplies the means of starting and stopping the carrier belt (3) at pleasure.

The dryer will hold about $1\frac{1}{2}$ tons, so, at a rate of crushing equal to 3 tons per hour, the ore will be $\frac{1}{2}$ hour travel-

ing through the furnace, a space of time believed to be quite (and more than) sufficient to dry it.

After passing between the first pair of rolls (4) the crushed ore (now about the size of corn) flows to the screen (5), and all that is fine enough taken out and allowed to flow at once to the elevator (7).

The coarse portion flows, by means of properly arranged and adjusted shutes (*c c*) to the second pair of rolls (6), which complete the crushing.

The object in taking out the ore which has been crushed sufficiently by the first rolls is twofold; namely, the portion already so reduced should be saved from further crushing, to prevent making too much fine stuff; and, secondly, as each machine is adjusted to crush finer than the one preceding, it is not capable of operating on the same weight or bulk of ore. The elevator (7) delivers all the crushed ore to the uppermost screen (8), which takes out any particles that may still be too coarse—such small percentage of coarse product being sent back through a shute (shown in the plate) to the first pair of rolls, for re-crushing. The portion passing through the meshes of the first screen flows to the second (9), and so much as goes through the second screen again to the third (10), and so on.

From the larger end of the second screen (9), we get the first or coarsest grade of ore for concentration, and which flows to the bin (12). From the end of the third (10) we obtain the second grade; and that from the end of the fourth screen (11) is the third grade, and what passes through the meshes of the fourth screen (11) is the fourth grade of ore, making in all 4 sizes, each size flowing to one of the four bins (12).

From the bins the ore flows directly downwards to the separator (13), situated on the floor below.

The tailings from the first eight separators are removed by any convenient means from the building, but the concentrated ore, with some gangue with it, flows to the con-

centrators (14), on the basement floor, where it is reconcentrated to remove all the gangue.

In practice it is found to be more convenient and economical not to concentrate too highly in the first operation, but to allow some gangue to go with the concentrated mineral. If the mineral contains some gangue it is an evidence there is no loss of valuable ore going off with the tailings, so the rich concentrations are allowed to flow to a single set of machines below, and there reconcentrated.

In this operation is obtained a pure concentrated mineral and a small amount of rich tailings, but this latter (rich tailings) is sent back by the elevator to be concentrated over again on the machine above (13).

A few hours of the 24 is sufficient time to do all the reconcentrating, as the bulk, compared to the original ore, is greatly reduced.

This system of reconcentrating renders good concentration easy, serves as a check to loss in the tailing and proves economical in practice.

The dust made by crushing is withdrawn through properly arranged dust pipes. The Exhaust Fan (15), for removing the dust, is connected with a main dust pipe (not shown) placed against the elevator trunk, and all dust pipes from Crushers, Separators and Screen Chambers, lead into the main pipe.

The screens are provided with latticed hoppers, which allows a current of air to flow freely up through the screen chambers, which removes the floating dust, but all which does not float in a gentle current flows to the bins (12), so that all grains not finer than $\frac{1}{240}$ part of an inch is concentrated. Each chamber is connected by separate dust pipes directly with the main tube.

The dust withdrawn from the various parts of the mill is conveyed through a tube and carried outside of the building some distance away to a dust chamber, as shown in the cut, where nearly all of it is settled and saved for subsequent treatment.

The importance of saving the dust, as well as the importance of making as little as possible in crushing, will be appreciated when it is understood that all the dust of ores assay always about double the value of the original in base and precious metals.

In order to produce as little dust as possible, in crushing at the rate of 2 to $2\frac{1}{2}$ tons per hour, 2 sets of rolls are indispensable and even 3 sets preferable and more economical. In this way the ore is brought gradually from coarse lumps to fine sand.

The machinery throughout the Mill is of the best possible workmanship; and each machine employed is constructed on the best known mechanical principles. No pains or money has been spared to bring each machine or other parts to a condition of working perfectly with all the rest, and also with the highest efficiency.

The Mill, constructed and fitted up as shown in the plan, is capable of crushing and concentrating at the rate of from 2 to 3 tons per hour.

Machinery and plans for mills of less or greater capacity will be furnished as may be required.

The number of men required to keep in operation a mill crushing and concentrating at the rate of 3 tons per hour, and when steam is the motive power, is:

6 men for day work and
3 " " night "

and when water is the motive power,

5 men for day work and
2 " " night "

The following on Ore Dressing is taken from Kustel's work on Concentration and Chlorination:

DRESSING OF ORES.

Ores, as found in the mines, are generally impure to a considerable extent, owing to an intermixture of foreign matters, although concentrated deposits of pure ore irregularly distributed are of frequent occurrence. Veins, yield-

ing mostly pure ores, free from intermixed earthy matters or gangue, and from which the metal can be directly extracted, are rare exceptions.

The great majority of veins contain the gangue predominant. The gangue is not the only stuff which renders the ore impure. Many intermixed metallic minerals are also considered as impurities, when they are not the objects of extraction, because either, under special circumstances, they may have no value in themselves, or they may occur in too small a proportion to pay for a separation; or the presence of their metals may be prejudicial to the metallurgical or mill process, causing loss of a more valuable metal, or making the process more expensive.

The earthy portion of the ores, such as quartz, lime, heavy spar, etc., is in some instances to a certain extent injurious to their treatment by different metallurgical processes. In every instance the expenses of reduction will rise with the increasing proportion of the earths.

This often happens to such an extent that the working of the ores ceases to be profitable.

Expenses of transportation, labor, fuel, fluxes, chemicals, power, etc., depend always more or less upon the bulk of the ore, which again depends principally on the relative quantity of earthy matters.

The presence of metals in the ore which are impurities, considered with reference to a certain metal in view, is generally productive of much inconvenience in metallurgical operations. One metal requires a different treatment from that which suits another, and one may have a bad effect on the quality and quantity of another which represents the object of extraction.

The separation of valuable matter from its intermixture with heterogeneous substances is called the dressing of ores. This term comprehends the mechanical separation generally—that is, the separation of gangue and worthless material from valuable ores—as well as the separation

of the ores themselves into different classes, according to different intended modes of treatment; the separation of gangue from ore by means of water is called concentration. Dressing includes concentration as one of its most important parts. The object of the "dressing of ores" is the separation of the worthless from the valuable portions as closely as possible with the least loss and the smallest expense. A very close separation is difficult and not always advisable. The less value a mineral contains, so much the closer may its separation from gangue be effected. Concentration consists in washing off the poorer or worthless parts from the ore.

Difference of specific gravity, or at least difference of the aggregate condition of the minerals, is the requirement for the possibility of separation. If, therefore, different minerals of the same specific gravity constitute the ore, or if minerals of different gravity are combined chemically, no mechanical separation can take place; but then a chemical process is sometimes first employed to produce a difference of specific gravity for the purpose of concentration. So, for instance, tin ore is generally accompanied by wolfram, molybdenum, arsenical iron and copper pyrites, zinc blende, copper glance, bismuth and antimonial ores, besides earthy minerals. In Cornwall, Bohemia and Saxony, tin ores are subjected to a concentration by means of water.

The concentrated ore contains all the wolfram, which is but little heavier than tin ore, most of the arsenical pyrites of nearly the same gravity as tin ore, and much of the iron and copper pyrites. This concentrated ore is then charged into a reverberatory furnace and roasted for the purpose of oxidizing the arsenic and sulphur combinations in order to change the specific gravity. The roasted ore is again concentrated, and sometimes, if the ore is very impure, the roasting and concentration is again repeated. The wolfram and tin ore remain unchanged—the former must be removed by a separate smelting process.

The Dry Concentrator separates the tin ore from the arsenical iron and copper pyrites without roasting, as the difference is sufficient to separate them in the raw state by means of air, another evidence of the superiority of air as the concentrating medium.

The sorting of useful ores into classes depends partly on the presence of different ores in the same ledge, as is often the case. For instance, silver ores, galena, zinc blende and copper ore may be associated in such a proportion that silver, zinc and copper can be extracted to advantage. In this case silver ore and galena must be separated from zinc blende and from copper ore; or if silver should be extracted by amalgamation, attention must be paid to the separation of silver ore from galena. Mechanical sorting is often much cheaper and simpler than chemical, which meets sometimes great difficulties in producing a pure article out of compound ores. Ores are also sorted for the purpose of classification into rich and poor ore of the same kind.

With proper working the percentage loss of metal of poor ores is higher than of rich ores. It is, therefore, always advisable to separate the rich from the poorer classes, if the character of the ore permits it.

PRINCIPLES OF DRESSING.

The dressing of ores is based on the following principles: First. Each constituent of the mass must be brought to the highest value which can advantageously be given to it. Second. The useful minerals must be concentrated only to the most advantageous degree of purity. Third. All loss of the quantity and value of the useful mineral must be avoided as far as practicable.

According to the first principle, we must endeavor to obtain each mineral with its highest value. It is very often the case that a deposit or vein carries different metallic minerals: for instance, galena, copper pyrites, iron pyrites,

blende, cobalt, ores, etc., which, in an isolated condition, command a certain highest price. If such ores were delivered unseparated, then not only would the subordinate metals remain unnoticed by the purchaser, but the value of the principal ores would be depreciated to some degree on account of the difficulty which would arise for the metallurgist in obtaining pure articles from the compound ores, being compelled to use a more complicated and expensive treatment for that purpose. If, however, these minerals were separated by dressing, the principal minerals would come up to their respective highest prices, and the mines would also realize the value of blende, besides, if this be treated for zinc. The pyrites may be made use of for the production of sulphuric acid, or the smelter may need it for the concentration of the silver in the matte, or for roasting of silver ores which are poor in sulphur.

With regard to the second principle, it would seem that, as a matter of course, the purest stuff would prove to be the most advantageous; but from a practical point of view it is different. The concentration should be continued only so far that, under the local circumstances, the most profit can be realized from the concentrated stuff. The more precious the metal is, the less advisable it is to concentrate it closely. There are many particulars to be considered as to what constitutes the most profitable degree of concentration. In this connection must be considered:

1. The mining expenses on the ore, or the purchase price of ores or tailings, the hauling, and all expenses on the ore till delivered at the place of concentration.
2. The cost of crushing, including all expenses connected with the work of concentration, transportation to the reduction works, cost of water, etc.
3. The loss sustained by concentration.
4. The expense of reduction and loss of metal thereby, and in what proportion the loss will appear with reference to the more or less concentrated matter; and, finally,

5. Whether the reduction, that is, the extraction of the metal, is effected in the same establishment, or in custom works.*

There seems to be a mistake in some places as to the proper degree of concentration, which misleads the inventors of concentrating machines, as well as those who wish to make use of concentration.

The leading principle of these machines is the extraction of pure sulphurets, and the putting through of a large quantity of stuff in the shortest time with the smallest apparatus under all circumstances.

Mere turning out the purest sulphurets is by no means a proof of the best contrivance, and can be looked upon often with suspicion of losing a great deal of rich, fine particles, if present.

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* If the reduction is to be performed in a custom mill, the conditions must be considered. In Nevada, for instance, it is the usage in some custom mills to charge for amalgamation of silver ores, by way of roasting, $50 per ton, without reference to the compounds, returning 80 per cent. of the value in gold and silver found by the fire assay. On account of distant hauling and the fixed charge, without reference to the richness, it might be more advantageous to concentrate closer. The following calculation will show how the degree of concentration is limited. For instance, a certain amount of ore or tailings is reduced by concentration to 10 tons (20,000 pounds), which would pay, according to an assay, $150 per ton. The value of these 10 tons, after deducting twelve per cent. of moisture, would be $1,320 00

Hauling, @ $4; charges, $50 per ton (dry); deduction of 20 per cent. 744 00

Return .... $ 576 00

Supposing now the above 10 tons were reduced by further concentration to 5 tons, and the loss by further concentration supposed to be 20 per cent., the value of these 5 tons, after deduction of 20 per cent., concentrating loss of the value above stated, would be $1,056 00

Hauling of 5 tons, @ $4; charges, $50 (for dry stuff); additional concentrating expense, $15; reduction loss, 20 per cent. 466 20

Return .... $ 589 80

The difference of $13.80 is in favor of closer concentration; other circumstances, however, may show a loss by over-concentration.

Very cleanly extracted sulphurets are often not only clean of earthy matters, but also of silver sulphurets, fine amalgam, etc. In some instances a close separation of sulphurets from earthy or other injurious matters is a condition for the further economical treatment of the educt.

With sulphuret of lead, copper sulphurets, etc., because of the low value of the metal, a close concentration must be effected. Auriferous pyrites require to be concentrated as close as possible for the chlorination process, unless the gangue is pure quartz, but it would be a great mistake if silver ores should be subjected to a close concentration.

As to the percentage which can be possibly obtained in concentration, it is not unusual to be assured by inventors of concentrators that they concentrate any ore within 5 or 10 per cent., an assertion the reason of which is either personal interest or more probably inexperience, but the statements are readily believed by customers. In the concentration of lead ores, galena principally, conducted on the best principles with all the improvements of modern concentration in Europe, where great attention and plenty of time are devoted to the operation, the loss is generally from 15 to 20 per cent. Saving 80 per cent. of lead ores in concentration may be considered a very satisfactory result. It must be borne in mind, moreover, that galena occurs in cubes; the cleavage is all cubic, very seldom fibrous; the specific gravity is 7.5—most favorable condition for concentration, while the specific gravity of the principal silver ores ranges from 5.2 to 6.2, and they have the disadvantage of assuming mostly a fibrous or leaf-like shape when pulverized. The silver sulphuret is heavier (7), but ductile. It is, therefore, quite proper to calculate on a loss of 35 to 45 per cent. (including loss in crushing) in treating silver ores, provided the plan for concentration is a proper one.

How differently silver ore behaves from lead ores in concentration is shown by the result of a concave buddle.

45 *d.* The nature of the ore certainly modifies the loss to a considerable extent. With the concentration of gold the case is different, for its high specific gravity allows a more perfect concentration; but, although under the most favorable circumstances from 90 to 95 per cent. of the gold may be saved, there are also cases where 30 per cent. and more might be lost; for instance, if the gold should occur in a very fine scaly condition in a clayey rock. A man, though experienced in concentration, cannot give an approximate estimate of the concentrating loss without having examined the nature of the ore in question, for the reason that the loss depends not only on the shape and gravity of the pulverized ore particles, but also very much upon the character of the gangue.

It may, moreover, occur that some earthy or metallic minerals mixed with the useful ore may be desirable for the reduction, so that a separation of the same would not only be useless but injurious, because the loss of the ore increases while the separation is going on, and because the ore may be more valuable if such minerals are not removed.

Professor Gaetzchmann mentions the following metals and minerals as injurious or otherwise with reference to the metal which is the object of extraction: "Iron and copper pyrites, and apatite, in iron ores (copper often accompanies spathic iron), while on the contrary spathic iron is not injurious to copper ores (other sorts of iron ores are not desirable with copper ores).

"Iron, copper, arsenical pyrites and zinc blende injure tin; bismuth makes its color dull, copper makes it brittle. Arsenic makes lead brittle; antimony hard. Lead with carbonate of zinc (galmey) or with blende spoils the zinc. Lead must be carefully separated from all kinds of ores out of which copper is to be extracted by precipitation or silver by amalgamation. In the first case it makes the copper impure; in the second it enters the quicksilver and causes

a greater loss in silver. Nickel-speiss (impure arsenuret) injures the amalgamation of silver ores. Injurious to cobalt (for the purpose of manufacturing blue paint) are, calc-brown and manganese-spar, horn stone, ferruginous quartz and galena. Nickel imparts, only when predominant, a red tinge (arsenic, on the contrary, intensifies the cobalt, and renders the color agreeable). Mica, lime, garnet, augite and horn-blende promote the fusibility of magnetic iron ore; fluor spar facilitates the smelting of lead, silver and copper ores. Spathic iron and heavy spar are advantageous in smelting lead ores; iron pyrites is useful for the production of matte."

In treating unwasted silver ores in iron pans, antimony is objectionable. If chemically combined with silver, it prevents the amalgamtion of silver ores more or less. Thirty per cent. of antimony (as a constituent part of the mineral) makes wasting indispensable. As a sulphuret antimony amalgamates under certain circumstances, especially if talc is present in the ore, and forms a bulky amalagam of sulphuret of antimony, causing a great loss in silver and gold. For similar reasons arsenical pyrites is injurious to silver and gold amalgamation.

Carbonate of lead must be carefully separated, it being easily decomposed. Galena is also decomposed, but with difficulty. Clay, talc and talcose slate deter amalgamation, causing also a greater loss in quicksilver; bale spar is favorable; iron, copper and zinc sulphurets are indifferent. Talc is also injurious in auriferous pyrites, if this be subjected to the chlorination process, for the purpose of extracting the gold. The talc in the chlorination tub absorbs too much chlorine gas.

It is therefore necessary to roast such stuff with from 1 to 5 per cent. of salt, according to the amount of talc.

In relation to the third principle, it is evident that a separation or concentration cannot be performed until the ore is reduced to some degree of fineness. During this process

a certain loss cannot be avoided; this loss must increase with the fineness of the pulverization. The loss in the quantity of the educt arises from too close, and the loss in the value from insufficient concentration.

It appears, therefore, most advisable to pulverize and to concentrate the ore only to such a degree as absolutely necessary. The dissemination of the valuable matter in the rock in coarser or finer condition is the guide as to what degree of pulverization is required. It is utterly impossible to prevent all loss in pulverizing the ore, but with sufficient care and proper management this loss may be reduced to a minimum. Much handling of the pulverized ore also occasions loss.

In order to carry out these principles a proper choice and succession of operations must be determined upon before hand, the important conditions in which are the following:

The ore must be subjected only to so many and such operations as are absolutely necessary to accomplish the purpose. Such methods must be adopted as are in accordance with local circumstances and the quality of the mass. The following points must be here considered: The nature of the material, that is, of the useful mineral, of the gangue and of the country rock, of which some is generally broken with the ore. Also in what condition the ore appears in the rock, whether disseminated in coarse particles or in coarse pieces, or only coating the rock in thin layers, as is the case with chloride of silver, native silver, etc. Also the structure must be examined, the cleavage, toughness, hardness, and what size and shape the mineral assumes when crushed.

(*a*) Cubic galena, iron and copper pyrites, for instance, require different and more simple operations than fibrous galena. Ore of the same kind with only one sort of rock is more easily separated than if mixed up with various rocks, as quartz, heavy spar, feld spar and lime. Native

gold, copper and silver hammer out into leaves or flat pieces, while galena, iron and copper pyrites form granular particles,—the latter, therefore, concentrate more perfectly. Ruby silver, brittle silver ore, blende and gray copper ore concentrate more difficultly, assuming a less favorable shape after crushing.

(*b*) Unfit for concentration, or very difficult, are decomposed silver and other ores, especially if easily converted into powder; malachite and argentiferous carbonates of lead and copper so often found in Nevada, Montana, etc.; chloride of silver, native silver in leaf or scale shape, plumbic ochre, cinnabar, etc.

Quartz, heavy spar, gray wacke, admit the precipitation of ore particles more easily than talcose or clayey rock, clay slate or gneiss

Great care must be taken not to disperse or scatter the ore particles in the mass by fine crushing, or by still more injurious grinding.

It is difficult to effect the separation of blende, copper, iron and arsenical pyrites and heavy spar from silver ores, wolfram from tin ores, chlorite and epidote from copper ores, spathic iron from copper pyrites and galena.

Pan tailings from unroasted silver ores are often subjected to concentration for the undecomposed sulphurets. This material contains a great deal of metallic iron, partly from the stamps, but principally from the shoes and dies of the grinding pan. The iron of such tailings, if exposed to the air for several weeks, will oxidize, and in connection with other iron particles form light, voluminous little bunches, involving sulphurets and amalgam. These very numerous voluminous particles cannot be retained with the heavier clean sulphurets, no matter what method of concentration may be adopted, but flow off with the water before the sand.

If, therefore, valuable tailings are intended for concentration which could not be executed immediately, they should be kept under water.

According to the preceding, it is obvious that a proper conduction of the dressing requires a knowledge of the physical and chemical nature of the metallic and earthy minerals, and of the value and richness of the orey matter; knowledge of the particular metallurgical treatment to which the ore is to be subjected is also required, in order to be able to judge whether the cost of a closer concentration would be justified by the advantage which the metallurgist would derive therefrom, while also taking into account the mining expenses, which augment or reduce the quantity of concentrated matter. It requires practice on the part of the operator and conscientiousness, that he may be aware of the real amount of loss suffered by dressing, and know all contrivances of ascertaining the same.

The inventors of concentrating machines are often unscrupulous enough as to the resulting performance of the concentrator, and frequently deceive themselves for want of experience.

The following, on the subject of "Ore Dressing," is taken from U. S. Commissioner Raymond's report of 1873, page 425:

"All ores, as they come from the mines, consist of two, and may consist of three, portions. There are always a valuable and a worthless portion, and there may be an injurious portion, the presence of which causes loss in the subsequent treatment of the ore. It is purely an economical question whether the worthless and inert, and the active and injurious, portions should be removed by mechanical means from smelting-ores, before they are subjected to chemical treatment in the furnace. To separate these portions by mechanical means is the province of ore dressing.

"The early mining operations in the Territories consisted almost exclusively in the extraction and amalgamation of ores containing the precious metals in a free state, and the high cost of labor, fuel and transportation entirely precluded the adoption of the processes of metallurgy by which the base metals could be extracted, and the loss of the precious metals themselves could, as a rule, be materially lessened. Smelting-ores were then but little sought after, and veins containing ore that could not be amalgamated without being previously subjected to a metallurgical process were practically valueless.

"But, at the present day, the ores of some of the richest mining districts are, and must be, worked by smelting alone, and in other places smelting works could be profitably carried on were the proper means at hand for preparing the ore for the furnaces. It is also claimed that in certain districts, at the present time, ores are smelted at a profit, which could much more profitably be worked by a previous dressing; and this is undoubtedly the case when the ore consists of argentiferous galena without tetrahedrite, or any of the exceedingly rich silver ores, the cleavage of which

causes them to break up into pieces of a shape ill suited for dressing.

"The cost of transportation is still generally so high at the West, that the smelting of lead ores, which do not contain from 30 to 50 ounces of silver to the ton, can hardly be thought of. The value of the lead obtained from the smelting of argentiferous galena may often be sufficient to pay something more than the cost of transporting the base bullion to market, and the same may be said more frequently of the copper contained in ores, mattes, or black copper, but only in exceptional cases will the base metal also cover a portion of the mining and smelting expenses. The accompanying base metal renders the payment of the insurance rates on fine bullion unnecessary, and the saving thus effected will go far towards paying the freight on the base metals.

"Dressing works are properly adjuncts to smelting works, and *vice versa.* In some localities silver ores are found of sufficient richness to be smelted without previous preparation, but instances in which a proper dressing would not be advantageous are rare. Even in rich ores there is usually much more earthy matter than is necessary for the formation of sufficient slag to protect the metal in the furnace, and the removal of this excess by dressing, before the ore comes to the furnace, would always be found economical.

"For example, the ores generally smelted in Utah contain a very much larger percentage of silica than can be used in slagging the oxide of iron and the alkaline bases which they contain, and in order to work these ores, fluxes, consisting of iron-stone or lime-stone, or a mixture of the two, must be employed in the furnace. The removal of a portion of the silica by mechanical dressing would save not only the cost of the fluxes, but the expense of smelting a much larger quantity of slag than is required.

"It is claimed by some that decomposed ores, such as

the carbonates of lead found in the Emma, Miller, and many other leading mines near Salt Lake, might also be dressed to advantage. This would entail the loss of almost all of the oxide of iron which they contain, but proportionally much more silica could be removed.

"Another and a not less important function of dressing is the removal of substances which act injuriously in the smelting process, causing irregularity in the working of the furnace, and loss by volatilization, or otherwise, of both base and precious metals. In this respect we see the difference between a true dressing of an ore and a simple concentration, which aims merely at removing a portion of the worthless gangue, and which divides the ore from the mines into but two portions—headings and tailings. By means of a rational and comprehensive system of dressing, however, the galena, the pyrites and the blende, which may have been intimately associated in the ore as it came from the mine, may be separated cleanly enough for all practical purposes, and each subsequently treated for itself. The advantage of making a complete separation of this kind will be apparent when we consider that the blende, which is so commonly associated with silver-bearing galena, is often poor in silver, and when put in the lead furnace, not only consumes a considerable quantity of heat in being volatilized or smelted into the slag, but carries with it, up the chimney or into the slag, a much greater amount of silver than was contained in it when it was put in the furnace. If, however, this zinc-blende can, with only a small percentage of galena, be treated by itself, it can be used for the preparation of zinc-white (Bartlett's process), and a large proportion of its contents of silver saved, or by different treatment, metallic zinc may be made from it. It is apparent, however, that the loss arising from the presence of zinc in the lead furnace, added to the value of the zinc and silver which may be saved, might not always be sufficient to pay the cost of dressing the ore, and as the question is

purely an economical one, it will be necessary for any one working such an ore to decide, in his individual case, as to whether dressing would be pecuniarily advantageous to him or not. In deciding this question, the best method of separation must be first determined, and the cost of dressing the ore by that process ascertained; then the loss of silver in the furnace caused by the volatilization of the zinc must be estimated with all possible care from assays, and from comparison with other cases in which similar ores have been smelted with, and without, previous dressing. Hence it will be seen that the question is by no means a simple one, after all. Technical knowledge, experience and sound business judgment are necessary for its proper solution, and all that can reasonably be expected from a dissertation on the subject of ore dressing, is that the cheapest and most approved methods of dressing shall be given, together with descriptions and illustrations of machinery which have not appeared in previous reports of the Commissioner, and, as far as possible, the data from which the cost of constructing and operating such machines may be reckoned with tolerable accuracy, in different districts and under different circumstances. It is evidently impracticable to give, in the limits of the present chapter, either the exact cost of dressing in any particular case, or the metallurgical losses which are caused by the presence of the injurious substance. The aid of skilled metallurgists should be called to solve the question, which is both too complicated and too important to be decided by any one else.

"From what precedes, it is clear that before we reach the final product of the mining and smelting operations, the metal itself, the earthy portions of the ore must be got rid of. The economical question is, whether it is cheaper to wash away a considerable portion of this dead mass, or to put it in the furnace and smelt it up along with the productive portion. Any *concentration* will remove a portion

of the unproductive part, and no economical system will perfectly separate every trace of it. We are compelled, therefore, to resort to a partial separation, if we resort to any, and the question, how far it will pay to go, becomes the important one. It would not usually be desirable to separate every trace of gangue from the ore, even if we could. What is left in the ore forms a slag which protects the metal in the hearth of the furnace from the oxidizing influences of the blast, and were no earthy material present in the ore, it would be necessary to add some for the purpose alluded to. If the ore is to be transported for great distances, the cost of transporting worthless material should be taken into account; but, under other circumstances, it is not desirable to pass a certain limit in the concentration, which must be determined, as before, by actual study and experiment."

"DRESSING OF ORES."

"In metalliferous veins the deposits of ores are extremely irregular and much intermixed with gangue or vein stone. In excavating the lode, it is usual for the miner to effect a partial separation of the valuable from the worthless portion; the former he temporarily stows away in some open place underground, whilst the latter is either employed to fill up useless excavations, or in due course sent to surface to be lodged on the waste heaps. From time to time the valuable part of the lode is drawn to the top of the shaft, and from thence drawn to the dressing floors, where it has to be prepared for metallurgical treatment.

This process is known as dressing, and in the majority of instances includes a series of operations. In this country it is chiefly restricted to mechanical treatment, the chemical manipulation being performed by the smelter.

Hand labor, picking, washing, sizing and reducing machinery, together with water concentrating apparatus, comprise the usual resources of the dresser, but sometimes he may find it useful to have recourse to the furnace, since it may happen that by slightly changing the chemical state of the substances that compose the ore, the earthy parts may become more easily separable, as also the other foreign matters. With this view the ores of tin are often calcined, which, by separating the arsenic and oxidizing the iron and copper, furnishes the means of obtaining, by the subsequent washing, an oxide of tin more pure than could otherwise be procured. In general, however, these are rare cases; so that the washing almost always immediately succeeds the picking, crushing or stamping processes.

Before entering upon the description of machinery employed in the concentration of ores, it is important to no-

tice the principles upon which the various mechanical operations are based. If bodies of various sizes, forms and densities be allowed to fall into a liquid, in a state of rest, the amount of resistance which they experience will be very unequal, and consequently they will not arrive at the bottom at the same time. This necessarily produces a sort of classification of the fragments, which becomes apparent on examining the order in which they have been deposited.

If it be supposed that the substances have similar forms and dimensions, and differ from each other in density only, and it is known that the resistance which a body will experience in moving through a liquid medium depends solely on its form and extent of surface, and not on its specific gravity, it follows that all substances will lose under similar circumstances an equal amount of moving force.

This loss is proportionally greater on light bodies than in those having more considerable density. The former, for this reason, fall through the liquid with less rapidity than the denser fragments, and must, therefore, arrive later at the bottom, so that the deposit will be constituted of different strata, arranged in direct relation to their various densities—the heaviest being at the bottom and the lightest at the top of the series.

Supposing, on the contrary, that all the bodies which fall through the water possess similar forms and equal specified gravities, and that they only differ from each other in point of volume, it is evident that the rapidity of motion will be in proportion to their sizes, and the larger fragments will be deposited at the bottom of the vessel.

As the bodies on starting are supposed to have the same forms and densities, it follows that the resistance they experience whilst descending through water will be in proportion to the surface exposed, and as the volumes of bodies vary according to the cubes of their corresponding dimensions, whilst the surfaces only vary in accordance with the squares of the same measurements, it will be seen that the

force of movement animating them is regulated by their cubes, whilst their resistance is in proportion to their squares.

If, lastly, it be imagined that all the fragments have the same volume and density, but are of various forms, it follows that those possessing the largest amount of surface will arrive at the bottom last, and consequently the upper part of the deposit will consist of the thinnest pieces.

It is evidently then of the greatest importance that the grains of ore which are to be concentrated by washing should be as nearly as possible of the same size, or otherwise the smaller surface of one fragment, in proportion with its weight, will in a measure compensate for the greater density of another, and thus cause it to assume a position in the series to which, by its constitution, it is not entitled.

This difficulty is constantly found to occur in practice, and in order as much as possible to obviate it, care is taken to separate by the use of sieves and trimmels into distinct parcels, the fragments which have respectively nearly the same size. Although by this means the grains of ore may to a certain extent be classified according to their regular dimensions, it is impossible by any mechanical contrivance to regulate their forms, which must greatly depend on the natural cleavages of the substances operated upon; hence this circumstance must always in some degree affect the result obtained.

Each of the broken fragments of ore must necessarily belong to one of the three following classes: The first class consists of those which are composed of the mineral sought, without admixture of earthy matter. The second will comprehend the fragments which are made up of a mixture of mineral ore and earthy substance; whilst the third division may be wholly composed of earthy gangue, without the presence of metallic ore. By a successful washing, these three classes should be separated from each other.

The most difficult and expensive vein stuff for the dressing floors is that in which the constituents have nearly an uniform aggregation, and where the specific gravity of the several substances approximate closely to each other.

In such case the ore is only separated from the waste after much care and labor, and often at the loss of a considerable portion of the ore itself. When, however, the ore is massive and distinct from the gangue, and the specific gravity of the latter much less than the former, then the operation of cleaning is usually very simple, effected cheaply, and with but little loss on the ore originally present.

The losses which may be sustained in the manipulation and enrichment of ores is a matter of great importance, and demands not only direct attention from the chief agent, but also calls for the constant vigilance of the dresser.

No one can approve of a system which omits to record the initial quantity of ore brought to the service, noting only the tonnage and percentage of the parcel produced for sampling.

Yet such inattention prevails generally in the mining districts of this country. What would be thought of a smelter who might systematically purchase and receive ores without ascertaining their produce, and reduce them in furnaces totally unfitted for the purpose, without regarding the losses which might be sustained? If he became insolvent it would excite no surprise, but, on the contrary, the public would most likely look upon his position as the inevitable result of a defective and reprehensive mode of working.

It will be admitted that mineral exploitations are of a highly hazardous nature, and that the risk of profit ought not be increased either by ignorance or carelessness. When ores are discovered, usually after the expenditure of much money, a certain amount of productive and dead cost is incurred before they can be rendered at the dressing floors;

if, then, the least waste takes place, there is not only a loss *per se*, but the mine expenditure is augmented upon the lessened quantity; hence, in no department of mining economics is it more essential to secure higher practical talent than in the dressing and management of vein stuff. The individual entrusted with this duty should be competent to assay the ores, have a knowledge of the losses resulting from their metallurgical treatment, and know approximately the cost of enriching them on the floors as well as of smelting them; he will then conduct his operations so that the cost and loss in dressing will be less than the cost and loss in smelting.

Some of the more friable ores, when simply exposed to the influence of water, exhibit a large mechanical loss—so much so, that it is considered oftentimes more profitable to put them to pile without attempting their enrichment. Now, it may be laid down as an axiom that water will always steal ore, and the longer it is exposed to its influence and the more complicated the manipulation, the greater will be the loss incurred. In addition, the constitution of certain ores is so peculiar and delicate, that any attempt to concentrate them beyond a given standard, by varying the treatment, is seen to lead to an enormous loss, as will be apparent by inspecting the following memoranda of practical results.

(*A.*) The ore operated upon was sulphide of lead, associated with finely disseminated iron pyrites, oxide of iron, quartz, and a small portion of clay slate. In each case the vein stuff assayed 17 per cent. of metal.

	Quantity by Weight.		*Quantity by Weight.*		
Assay'd 17 per ct.	1	washed and concentrated to	.25	The loss on metal originally present in the ore by varying the mechanical treatment was	61 per ct.
	1	" " " "	.40		39 "
	1	burnt, roasted and " "	.20		57 "
	2.4	washed " " "	.43		37½ "
	1.56				
	20	loss by roasting.			
	1.36	washed and concentrated to	.40		50 "
	.8	roasted, washed and " "	.42		33 "
	.8	" " " " "	.69		16¾ "

(*B.*) Took two parcels of argentiferous lead ore, associated with carbonate of iron, a little quartz and blende. Weight $34\frac{6}{20}$ tons, which assayed $42\frac{1}{2}$ per cent. for lead, and 29 oz. of silver per ton of metal. Crushed and carefully elaborated the same through jigging and buddle apparatus, obtained $14\frac{13}{20}$ tons of ore, giving $54\frac{1}{2}$ per cent. for lead, and 22 ounces of silver per ton of metal. The produce for lead was therefore raised 12 units at a loss of 49 per cent. of the initial quantity of metal and 95 ounces of silver. The commercial loss attending this operation, after making the several charges and allowances incident to the metallurgical reduction, was £91 14s., or equal to £2 14s. per ton on the original weight.

Additional instances of heavy losses incurred in the concentrating process could be adduced if space permitted; but it may not be unwise to direct special attention to the great waste often connected with the manipulation of both tin and argentiferous ores. In the fomer it occurs chiefly from the oxide of tin being much diffused through hard vein stone, requiring severe mechanical treatment in order to liberate it, whilst in the latter the silver (not unfrequently combined mechanically), imperceptible to the eye, floating away when subjected to water, and so subtle as to evade the most delicately devised apparatus.

The loss accruing in one large undertaking from this source alone upon 1,100 tons of ore was 3,026 ounces of silver, worth £830, or equal to the interest on £16,600, at the rate of 5 per cent. per annum.

In order to determine the loss of metal which may arise in enriching ores, accurate assays and notations should be made of the quantity of vein stuff lodged on the floors, which should be compared with the metallic contents rendered merchantable, and the differences estimated.

It is not possible to ascertain the value of an improvement which would secure an additional one per cent. from the quantity of orey stuff annually sent to surface from

the several mines in the United Kingdom; but if it be reckoned only upon the sale value, it would be scarcely less than £40,000 per annum.

In determining the site for a dressing floor, and in the mechanical arrangements, various points suggest themselves; since, if they were overlooked, much loss would ensue to the undertaking, or otherwise it is evident that they could only be corrected by involving the proprietary in an increased outlay as well as a greater current expenditure. The first consideration should be to secure an ample supply of water, with a good fall, and an extensive area of ground. With advantages of this nature the machinery will be worked cheaply, the stuff gravitate through the various processes without returning to create double carriage expenses, whilst the castaways may be sent to the waste heaps at a minimum cost. The second point to be settled is the class of machinery to be employed. This must obviously be based upon the character which the ores may present. If massive and associated with light waste, simple apparatus will suffice; but if the ore be sparsely diffused among heavy vein stone, it is probable that the various apparatus will have to be constructed with great nicety, varied in their principles of action, and that much precaution will have to be observed in order to create as little slime as possible, as well as to secure the initial quantity of ore against undue loss. In the disposition of the machinery there is also considerable scope for practical intelligence; it is not enough to wash, crush, jig and buddle the ores, mixing the resulting smalls incongruously together; but a judicious sorting should be commenced at the wash kilns, and upon this basis the various sizes kept distinct whilst passing through the washing floors. The dresser should always take care to keep the several ranges of mineral produces and degrees of fineness together.

The following general deductions will be found serviceable :—

First. Absolute perfection in separation, according to specific gravity, cannot be arrived at, chiefly on account of the irregularity of form of the various grains to be operated upon.

Second. The more finely divided the stuff to be treated, the greater is the amount of labor and care required, and the more imperfect will be the separation.

Third. That reducing machine may be considered the most perfect which produces the least quantity of stuff finer than that which it is intended to produce.

Fourth. It is necessary, in determining the degree of fineness to which a mineral should be reduced, to consider the metallurgical value of the ore contained in it, and to set against this the value of the loss which will probably be incurred, together with the labor and expense attendant upon the manipulation.

Fifth. The vein stuff should be reduced to such a degree of fineness, that the largest proportion of deads and clean ore should be obtained by the first operation, thus saving the labor and preventing the loss incident to a finer subdivision of the ore and more extended treatment.

Sixth. That apparatus or plan of dressing may be considered the most efficient which, with stuff of a given size, allows at an equal cost of the most perfect separation, and of the proper separation of stuff of nearly equal specific gravity.

The average percentage to which the crop is to be brought, and the highest percentage to be allowed in the castaways being determined, it is evident that the more perfect the degree of separation, the greater will be the amount of crop and castaways obtained at each operation, and the quantity of middles or stuff to be re-worked will be diminished.

Seventh. We may further consider as a great improve-

ment in dressing operations such apparatus or plan of working as will allow, without a disproportionate increase in the cost, of the equally perfect separation of fine stuff as that of the coarser, as now practiced. This will be of especial benefit in the case of finely disseminated ore, which is necessarily obliged to be reduced to a great degree of fineness."

[*From Supplement to Ure's Dictionary*, 1873.]